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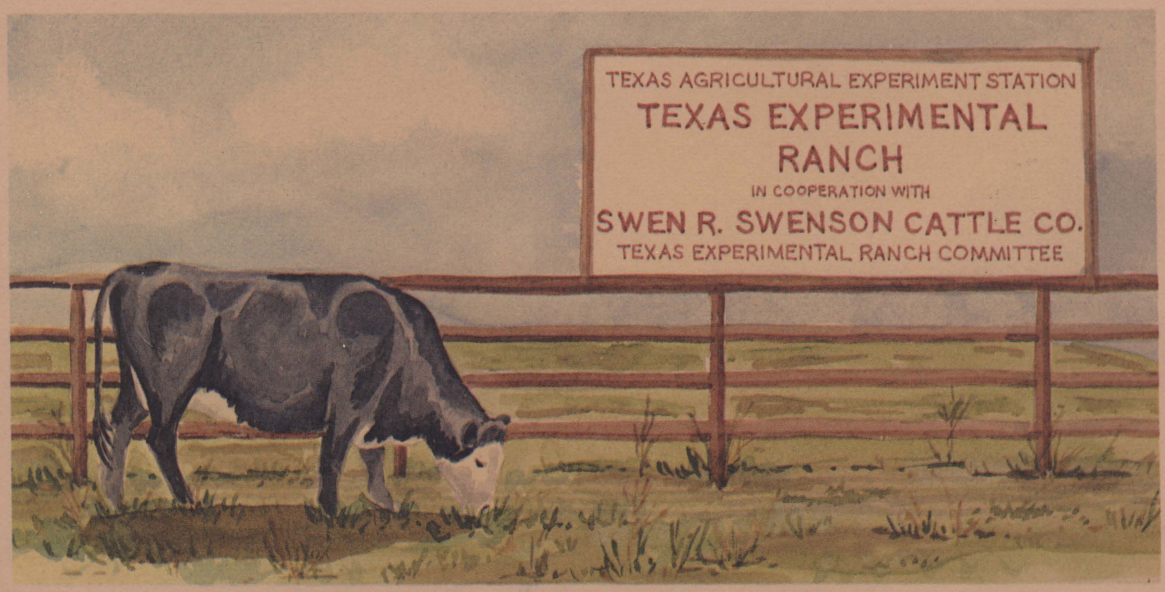
RESPONSE OF VEGETATION TO LIVESTOCK GRAZING AT THE TEXAS EXPERIMENTAL RANCH



THE TEXAS AGRICULTURAL EXPERIMENT STATION/Neville P. Clarke, Director/The Texas A&M University System/College Station, Texas

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Response of Vegetation to Livestock Grazing at the Texas Experimental Ranch

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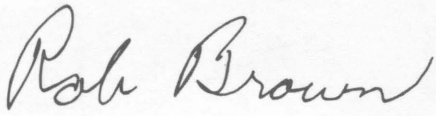
Key Words: Grazing systems, stocking rate, forage production, species composition, range site.

Foreword

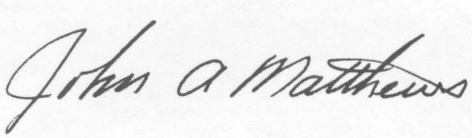
An understanding of the principles of grazing management is essential for the successful management of any ranching enterprise. Because these principles are based primarily on an understanding of the ecological response of the native forage to various grazing management practices, grazing management research often requires a longterm commitment of considerable resources. These commitments were made with the establishment of the Texas Experimental Ranch.

The 7,000-acre ranch was created in 1959 to provide research scientists an opportunity to determine both the short-term and long-term effects of various grazing management practices on both livestock production and the native vegetation. It was created from a cooperative agreement between a group of interested ranch and businessmen, the Swenson Land and Cattle Company, and the Texas Agricultural Experiment Station. The businessmen formed the Texas Experimental Ranch Committee for the purpose of securing funds for construction of necessary improvements such as fences, watering tanks, and headquarter buildings. The committee has continued to function in this role over the past 25 years as well as act in an advisory capacity to the research scientists and administrators who are associated with the ranch. The Swenson Land and Cattle Company agreed to provide the necessary land and cattle needed to implement the research. The current owners, the Swen R. Swenson Cattle Company, continue to provide these valuable resources. The Texas Agricultural Experiment Station provides the necessary funds and personnel to maintain this unique research facility.

The ranch and this publication are truly a product of the combined efforts of many individuals. Data included in this publication were collected over a 22-year period and reflect the dedicated work of many people. Specific appreciation is expressed to the many project leaders, research associates, technicians, and student workers who assisted in this endeavor. Specific thanks are extended to Dr. W. J. (Dub) Waldrip, initial project leader at the ranch, for his contribution in developing and initiating the long-term studies. Appreciation is also expressed to the many employees of the USDA Soil Conservation Service who assisted in this study and specifically to Mr. Clyde Lowther, USDA-SCS soil scientist, for the many hours he has spent at the ranch mapping soils and developing soil descriptions. We also acknowledge the contributions of the Swenson Land and Cattle Company, the Swen R. Swenson Cattle Company, and past and present members of the Texas Experimental Ranch Committee.



Rob Brown, Co-chairman
Texas Experimental Ranch Committee



John Matthews, Co-chairman
Texas Experimental Ranch Committee

Response of Vegetation to Livestock Grazing at the Texas Experimental Ranch

R. K. Heitschmidt, S. L. Dowhower, R. A. Gordon, and D. L. Price*

The Texas Experimental Ranch is located on the eastern edge of the Rolling Plains resource area (Gould, 1975), and encompasses 2,900 hectares (ha). It was created in 1959 to provide research scientists with an extensive rangeland laboratory to evaluate the long-term effects of grazing management on cow/calf and vegetation performance. Since 1960, three grazing treatments have been continued in the same pastures without interruption: continuous grazing at heavy and moderate rates of stocking and a four-pasture, three-herd deferred rotation treatment stocked at a moderate rate. Previous studies have examined the long-term effects of these treatments on cow/calf performance (Heitschmidt et al., 1982) and economic profit (Whitson et al., 1982). The objective of this bulletin is to quantify the long-term effects of these grazing treatments on the native vegetation.

Study Area

Climate

Climatic conditions are characterized by warm, wet springs and falls, mild winters, and hot summers (Appendices 1, 2, and 3). Average annual precipitation is 682 mm (Figure 1) and bimodally distributed. Mean daily minimum temperatures range from −2°C in January to 22°C in July. Mean daily maximum temperatures range from 11°C in January to 36°C in July. The frost-free growing season generally extends from March to November.

Physiography and Soils

The ranch is located in the Central Lowland Physiographic Province (Godfrey et al., 1973). Topography is rolling and ranges from broad valleys and gentle slopes (1 to 3 percent) that lead to nearly level uplands (< 1 percent), to narrow secondary valleys with steep slopes (> 5 percent). Range in elevation is from 408 m to 463 m.

Soils at the ranch range from the deep, well-drained clay and clay loams found in the valleys and on the gentle slopes and upland, to the shallow, stoney clay and clay loams found on the steeper slopes (Figure 2). Parent materials are limestone bedrock and overlayed clayey sediments deposited by wind and water from the mantle cover of the High Plains (Godfrey et al., 1973). The High Plains mantle consists of Rocky Mountain sandy to clayey sediments originally deposited during late Tertiary, Pliocene, and Quaternary. For a complete description of dominant range sites and soils see Appendix 4.

Vegetation

Vegetation at the ranch is primarily a mixture of mid- and shortgrasses. Dominant midgrasses are sideoats grama, a warm-season perennial, Texas wintergrass, a cool-season perennial, and Japanese brome, a cool-season annual[1]. Dominant shortgrasses are buffalograss and common curlymesquite. Texas broomweed, a warm-season annual, is the dominant forb. Honey mesquite is the dominant woody plant, lotebush the dominant shrub, and brownspine pricklypear the dominant succulent. The entire ranch was aerially sprayed for control of honey mesquite in 1964 and 1972 with 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] and in 1979 for control of both honey mesquite and pricklypear with a mixture of 2,4,5-T and picloram (4-amino-3,5,-6-trichloropicolinic acid). A complete taxonomic list and ecological classification of all vascular plants found on the ranch is presented in Appendix 5.

Grazing Treatments

Three grazing treatments have been continued in the same pastures without interruption since 1959. These treatments are: (1) yearlong continuous grazing stocked at a heavy rate (heavy continuous-HC); (2) yearlong continuous grazing stocked at a moderate rate (moderate continuous-MC); and (3) a four-pasture, three-herd deferred rotation (deferred rotation-DR) stocked at a moderate rate. Four ungrazed exclosures (EX) were also established in 1959. Rate of stocking in the two moderately stocked treatments was gradually increased from 1960 to 1978 to maintain relatively constant stocking pressures (Figure 1). Treatments are replicated across pastures. Size of the two heavy continuous and two moderate continuous pastures is about 240 ha. Size of each of the four deferred rotation

[1]See Appendix 5 for scientific name of all plant species.

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pastures is about 120 ha. The four small exclosures range in size from 1 to 8 ha. For a more complete description of each grazing treatment, livestock management procedures, and livestock performance data, see Heitschmidt et al. (1982).

Methods

Vegetation sampling procedures varied among years. Initial sampling procedures (1960-78) were designed to monitor vegetation trends across time relative to both size and number of plants. Procedures since 1978 have focused primarily on quantifying vegetation changes after 20 years of treatment.

1960-78

Vegetation was sampled using a 10-point, 45° angle frame. Twenty-four permanent frame locations per 80 m²-sample plot were read each summer from 1960 through 1969, and in 1971, 1973, 1976, and 1978. At each location the frame was lowered vertically into the vegetation with all pins down until the legs of the frame and the pins touched the soil surface. The frame was then inclined to the 45° angle and each species and/or species groups touching each pin was recorded. Recorded species and species groups are presented in Table 1.

Originally, 333 permanent plots were located on five range sites. A more detailed soil survey in 1978 in combination with the most recent range site classifications revealed the 333 plots were located on 18 soil series representing 10 range sites. An inadequate number of sample plots (< 3) limited our data analyses to 14 soil series and 8 range sites. Number of plots per treatment by soil series and range sites is presented in Appendix 6.

Data were summarized by plot and statistically analyzed using least square linear regression models where Y equaled percent frequency of occurrence and X equaled number of years after initiating treatment. Frequency was calculated by dividing the number of hits for a given species by 240 which was the total number of pins read per plot. Models were developed only for those species or species groups that had a frequency in either 1961 or 1978 of at least 5 percent.

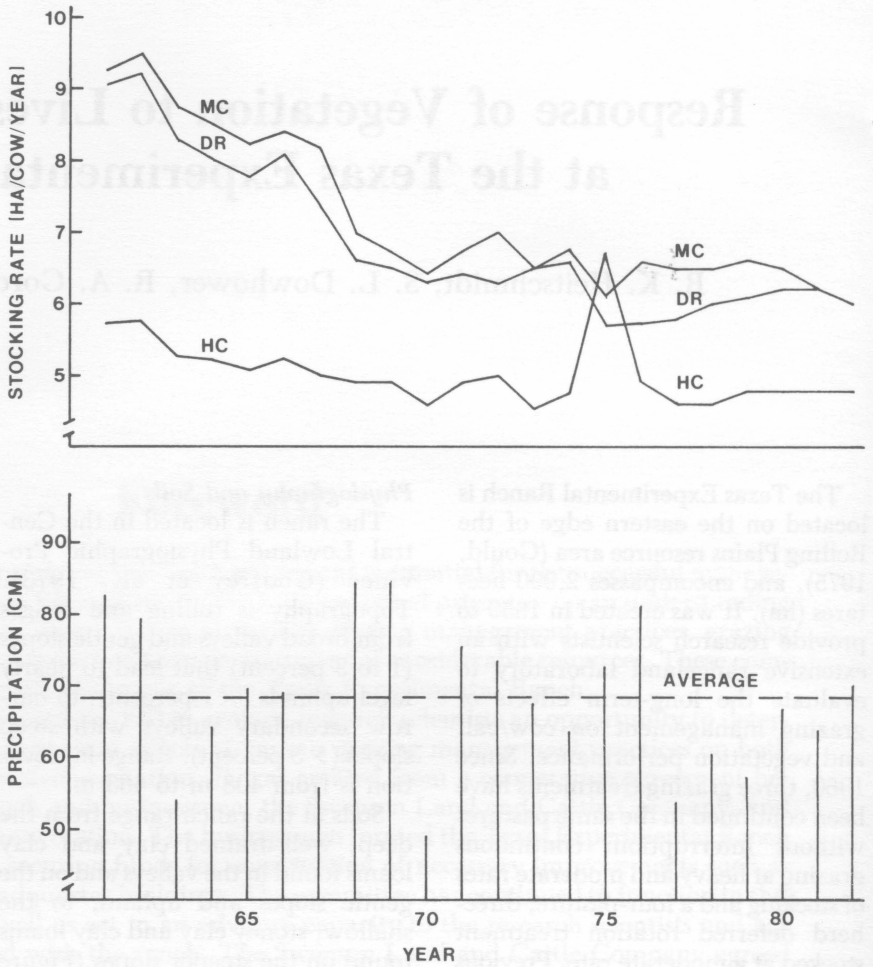

Figure 1. Total annual precipitation (cm), 23-year average, and annual rates of stocking for heavy continuous (HC), moderate continuous (MC), and deferred rotation (DR) grazing treatments.

1978-82

New vegetation sampling procedures were initiated in 1978 to monitor long-term vegetational changes induced by climatic fluctuations and livestock grazing. Method of sampling consisted of recording plant species present in 200 frequency quadrats per sample plot. Frequency of occurrence was recorded in two sizes of quadrats. The smaller size quadrat (10 × 10 cm) was located in the upper left corner of the larger quadrat (25 × 50 cm). The smaller quadrat provided a more sensitive measure of changes in frequency of the more abundant annual species that occurred in the larger quadrat (Hyder et al., 1975).

Twenty-four sample plots were selected as permanent plots from the 333 permanent plots originally sampled from 1960 through 1978. Sample plots were limited to the three dominant range sites found at the ranch. Each range site was sampled twice in each treatment. Range sites selected for study were rocky hills, clay loam, and loamy bottomland.

In addition to frequency data, potential aboveground net primary production (ANPP) was estimated during 1982 on the three range sites in the HC and MC pastures and the exclosures. At each location all aboveground standing crop was removed in February and four sets of paired quadrats were caged with wire exclosures. Total standing crop in one quadrat of each pair was harvested in June near the time of

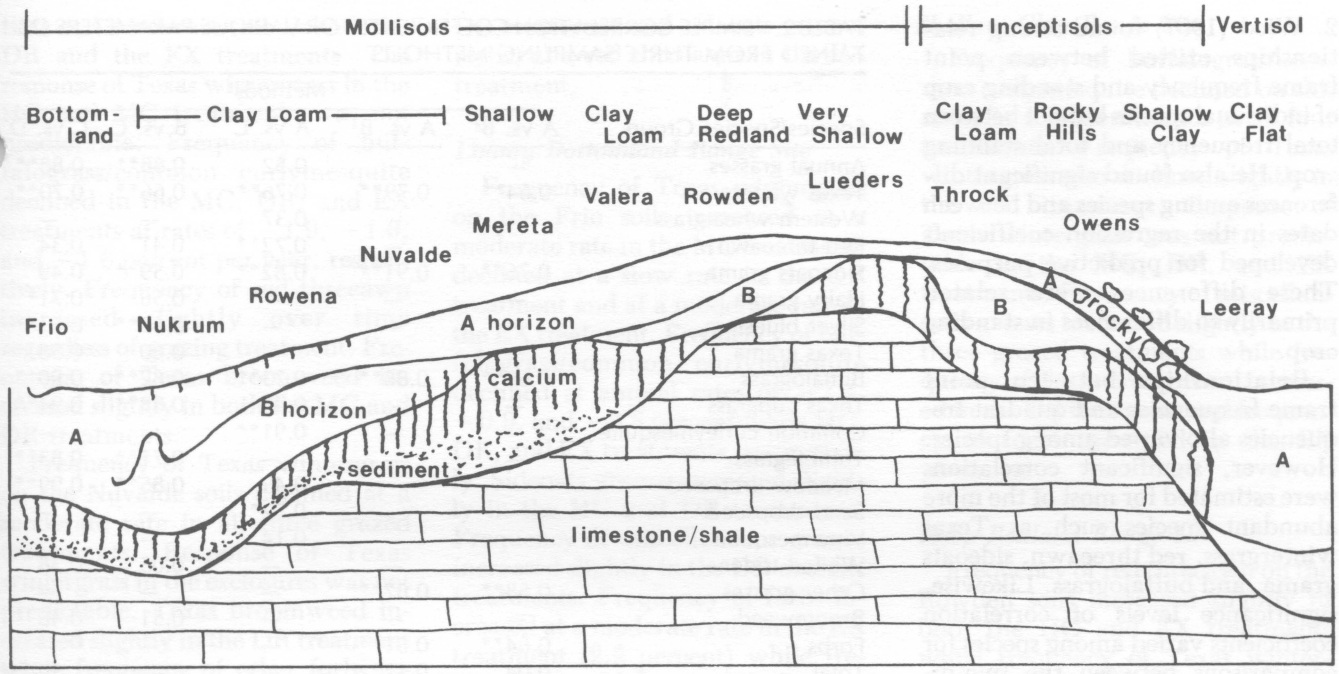

Figure 2. Horizontal profile of major soils and associated range sites.

TABLE 1. ABBREVIATED CODES FOR SPECIES AND SPECIES GROUPS THAT WERE MONITORED FROM 1961 THROUGH 1978 IN PERMANENT FREQUENCY PLOTS

Common Name	Code
Buffalograss and/or common curlymesquite	BUDA/HIBE
Texas wintergrass	STLE
Sideoats grama	BOCU
Annual grasses	ANGR
Red threeawn	ARLO
Sand dropseed	SPCR
Meadow dropseed	SPAS
Texas cupgrass	ERSE
Blue grama	BOGR
Vine-mesquite	PAOB
Western wheatgrass	AGSM
Big bluestem	ANGE
Miscellaneous grasses	MISC
Texas broomweed	XATE
Other forbs	FORB

maximum live biomass. The second quadrat was clipped in October near the end of the growing season. All standing crop was harvested by species at ground level and dried at 60°C prior to weighing. ANPP was estimated by species by summing peak standing crops.

The ANPP data were subjected to standard analysis of variance procedures (Little and Hills, 1978). Mean separation procedures follow Tukey Q procedures as outlined by Snedecor and Cochran (1967). Frequency data were not statistically analyzed.

Relationship Between Sampling Methods

Knowledge of the relationship between sampling methods was considered essential for proper interpretation of these data. The inclined point frame method utilized from 1960 through 1978 provided an integrated measure of the frequency of occurrence of a species in both the horizontal and vertical planes. Frequency estimates obtained from this method were thus affected by not only the presence or absence of a species but also quantity of standing crop. The relationship betwen these frequency estimates and current standing crop was examined by Wied (1967).

The vegetative sampling method utilized from 1978 through 1982 provided an estimate of frequency of occurrence of a given species in only the horizontal plane. The relationships between this and the point frame method were examined utilizing standard correlation procedures (Draper and Smith, 1966) for estimates obtained in 1978 from 25 plots sampled with both methods. Likewise, similar correlation procedures were used to examine the relationship between frequency and standing crop, and between frequency and ANPP estimates. Data utilized in these analyses were from the 1982 sample plots located on the three range sites in the four grazing treatments. Correlation coefficients were developed for 14 species comparing frequency and standing crop estimates in June, and for comparing frequencies in June with ANPP estimates for the entire growing season.

Results

Correlation coefficients between estimates derived by the three sampling methods are presented in Table

2. Wied (1967) found strong relationships existed between point frame frequency and standing crop of individual species but not between total frequency and total standing crop. He also found significant differences among species and between dates in the regression coefficients developed for predictive purposes. These differences were related primarily to differences in standing crop.

Relationships between point frame frequencies and quadrat frequencies also varied among species. However, significant correlations were estimated for most of the more abundant species such as Texas wintergrass, red threeawn, sideoats grama, and buffalograss. Likewise, significance levels of correlation coefficients varied among species for comparisons between the two-dimensional quadrat frequencies and standing crop estimates, and between the two-dimensional quadrat frequencies and annual ANPP estimates. Significant correlations were established for most major species. A notable exception was sideoats grama. The absence of a significant correlation between frequency of sideoats grama in June of 1982 and estimated annual ANPP in 1982 may be related to the dynamic annual growth pattern of sideoats grama. In contrast to such species as Texas wintergrass, buffalograss, and various species of annual grasses, sideoats grama continued to grow throughout the 1982 growing season after the other species had completed most of their growth.

TABLE 2. SIMPLE CORRELATION COEFFICIENTS FOR VARIOUS PARAMETERS OBTAINED FROM THREE SAMPLING METHODS

	Methods[1]				
Species/Species Group	A vs. B[2]	A vs. B[3]	A vs. C	B vs. C	C vs. D
Annual grasses	—	—	0.52	0.88**	0.88**
Texas wintergrass	0.64**	0.79**	0.76**	0.66**	0.70**
Western wheatgrass	—	—	0.37	—	—
Red threeawn	—	—	0.72**	0.41	0.34
Sideoats grama	0.76**	0.91**	0.82**	0.59**	0.49
Hairy grama	—	—	—	0.56	0.71*
Silver bluestem	—	—	—	0.65**	0.63**
Texas grama	—	—	—	0.60	0.58
Buffalograss	0.69**	0.88**	0.73**	0.82**	0.90**
Texas cupgrass	—	—	0.45	0.88**	0.94**
Common curleymesquite	—	—	0.91**	—	—
Tumblegrass	—	—	—	0.71**	0.83**
Meadow dropseed	—	—	0.49	0.85**	0.99**
Sand dropseed	—	—	0.52*	—	—
Vine-mesquite	—	—	0.14	—	—
Whited tridens	—	—	—	0.05	0.38
Other grasses	0.68**	0.67**	—	—	—
Broomweed	—	—	—	0.51	0.46
Forbs	0.64**	0.51**	—	—	—
Total	0.04	0.17*	—	—	—

[1]A = frequency estimates derived from point frame (1960-1978). B = standing crop. C = frequency estimates derived from 2-dimensional quadrat (1978-82). D = estimated annual ANPP.
[2]July estimates from Wied (1967).
[3]November estimates from Wied (1967).
*Significant at P <0.05. **Significant at P <0.01.

Vegetation Trends (1960-78)

The 1960 through 1978 point frame frequency data are presented in Appendix 1, illustrating the linear models developed for each treatment by soil series and plant species. Only statistically significant ($P < 0.10$) linear models are presented. Species identification codes for the linear models are presented in Table 1. Models whose intercept did not differ significantly ($P > 0.10$) from zero are depicted with a zero intercept. Models with an intercept value in excess of 75 percent are presented with an intercept 10 percent less than actual. Actual intercept values for these models are printed in parentheses on the associated regression line.

Clay Loam Range Site

Frequency of Texas wintergrass on the Valera soils declined at a rate of about 2 percent per year in both the HC and DR treatments while frequency of red threeawn increased in both treatments at a rate near 0.5 percent per year. Frequency of buffalograss/common curlymesquite on the Throck soils declined at an annual rate of about 2 percent per year in both the MC and DR treatments and at a rate near 3 percent per year in the EX treatments. Response of buffalograss/common curlymesquite in the HC treatment was not predictable. Frequency of miscellaneous grasses increased slightly over time in the HC and DR treatments while frequency of red threeawn increased slightly in all three grazed treatments. Frequency of Texas broomweed increased slightly in the HC and DR treatments while frequency of other forbs increased in the MC and EX treatment. The MC treatment was the only treatment where frequency of sideoats grama increased. Frequency of Texas cupgrass increased slightly and frequency of sand dropseed decreased slightly in the EX treatment.

Frequency of Texas wintergrass on the Nukrum soils declined in the HC and MC treatments and increased in the EX treatment. Annual rates of response were −1.2, −0.6, and 1.7 percent, respectively. Response of Texas wintergrass in the DR was not predictable while frequency of red threeawn increased slightly in all three grazed treatments. Frequency of buffalograss/common curlymesquite declined at a low annual rate in the DR treatment (−1.3 percent) and MC treatments (−1.6 percent), and at a rapid rate in the Ex treatment (−4.0 percent). Frequency of sideoats grama and other miscellaneous grass species increased slightly in the MC treatment. Frequency of Texas cupgrass and forbs increased slightly in both the MC and EX treatments while frequency of sand dropseed in the exclosures decreased.

Frequency of Texas wintergrass on the Rowena soils declined over

time at a moderate rate in both the DR and the EX treatments. The response of Texas wintergrass in the HC and MC treatments was not predictable. Frequency of buffalograss/common curlymesquite declined in the MC, DR, and EX treatments at rates of −1.9, −1.0, and −1.6 percent per year, respectively. Frequency of red threeawn increased slightly over time regardless of grazing treatment. Frequency of Texas broomweed increased slightly in both the MC and DR treatments.

Frequency of Texas wintergrass on the Nuvalde soils declined at a moderate rate in all three grazed treatments. Response of Texas wintergrass in the exclosures was not predictable. Texas broomweed increased slightly in the DR treatment while frequency of other forbs increased at a moderate rate in the MC and DR treatments and at a rapid rate in the exclosures. Red threeawn increased slightly in the exclosures. Frequency of buffalograss/common curlymesquite declined at an annual rate of −3.3 percent in the exclosure. Response of buffalograss/common curlymesquite was unpredictable in the grazed treatments.

Rocky Hills Range Site

Trends in vegetation response on the Throck soils were only predictable in the MC treatment. Both sideoats grama and buffalograss/common curlymesquite declined at a moderate rate while frequency of other miscellaneous grasses increased at a moderate rate.

Clay Flat Range Site

Frequency of Texas wintergrass declined over time in the HC, DR, and EX treatments with rate of decline most rapid in the exclosures. Likewise, frequency of buffalograss/common curlymesquite declined in the DR and EX treatments but at a more rapid rate in the exclosures than the DR treatment. Response of buffalograss/common curlymesquite was not predictable in the HC treatment. Frequency of miscellaneous grasses increased slightly in the HC and EX treatments as did sideoats grama in the DR treatment and sideoats grama, forbs, and red threeawn in the EX treatment.

Loamy Bottomland Range Site

Frequency of Texas wintergrass on the Frio soils increased at a moderate rate in the MC treatment, declined at a slow rate in the DR treatment and at a moderate rate in the EX treatment. Frequency of buffalograss/common curlymesquite declined at annual rates of −2.4, −0.9, and −2.8 percent in the MC, DR, and EX treatments, respectively. Sideoats grama increased slightly in the HC and DR treatments. Frequency of miscellaneous grasses increased slightly in the DR and EX treatments. Frequency of forbs increased at a moderate rate in the EX treatment (2.2 percent) while frequency of sand dropseed declined at a rate of −1.1 percent per year.

The response of the vegetation on Spur soils was only monitored in the HC treatment. Frequency of buffalograss/common curlymesquite increased at an annual rate of 1.4 percent. Frequency of miscellaneous grasses decreased slightly while frequency of red threeawn increased slightly.

Very Shallow Range Site

Frequency of buffalograss/common curlymesquite declined slightly on the Leuders soils in all three grazed treatments. Frequency of Texas broomweed increased slightly in the HC and DR and treatments. Frequency of miscellaneous grasses also increased slightly in the HC treatment.

Shallow Range Site

Frequency of buffalograss/common curlymesquite declined at a moderate rate on the Mereta soils in the MC, DR, and EX treatments as did the frequency of Texas wintergrass in the DR and EX treatments. Red threeawn increased at a moderate rate in the MC and DR treatments. Likewise, frequency of forbs and Texas cupgrass increased in the EX treatment, frequency of Texas broomweed increased in the DR treatment, and frequency of sideoats grama increased in the MC treatment.

Shallow Clay Range Site

Frequency of buffalograss/common curlymesquite declined on this series at a moderate rate in all four treatments. Frequency of Texas wintergrass also declined slightly in the HC treatment. Response of Texas wintergrass was not predictable in the MC, DR, and EX treatments. Frequency of miscellaneous grasses increased slightly in the three grazed treatments while frequency of Texas broomweed increased in the DR treatment and frequency of forbs increased in the EX treatment.

Deep Redland Range Site

Frequency of red threeawn on the Rowden soils increased slightly in both the HC and EX treatments while frequency of Texas wintergrass, buffalograss/common curlymesquite, and sand dropseed declined in the Ex treatment. Frequency of forbs increased at an annual rate of 1.7 percent in the EX treatment.

Frequency (1981-82)

Clay Loam Range Site

Dominant grasses (greater than 50 percent frequency) on the Throck soils in the HC treatment were Texas wintergrass and buffalograss (Table 3). Subdominants (greater than 25 percent frequency) were red threeawn and tumblegrass. The dominant forb (greater than 25 percent frequency) was redseed plantain. The dominant grasses in the MC treatment were Japanese brome and Texas wintergrass with buffalograss a subdominant. The dominant forbs were redseed plantain and annual broomweeds. The dominant grass in the DR treatment was sideoats grama. Subdominants were Texas wintergrass, red threeawn, and buffalograss. No forbs had a frequency greater than 25 percent. The dominant grass in the EX treatment was Texas cupgrass. Subdominants were Texas wintergrass, sideoats grama and slim tridens. The dominant forb was heath aster.

On the Nukrum soils, the dominant grasses in the HC treatment were Texas wintergrass, buffalograss, and tumblegrass (Table 3).

TABLE 3. FREQUENCY (PERCENT) OF DOMINANT SPECIES ON FIVE SOIL SERIES, FOUR RANGE SITES IN THREE GRAZING TREATMENTS. FREQUENCY VALUES ARE AVERAGE FOR TWO REPLICATES ACROSS TWO YEARS (1981 AND 1982). FREQUENCIES OF ANNUAL SPECIES ARE FROM 10 BY 10 CM FRAME. FREQUENCIES OF PERENNIAL SPECIES ARE FROM 25 BY 50 CM FRAME. SPECIES INCLUDED WERE THOSE WITH A FREQUENCY ×20% ON AT LEAST 1 REPLICATE OF 1 SITE IN 1 YEAR

	Loamy Bottomland				Clay Flat				Clay Loam[1]				Clay Loam[2]				Rocky Hill			
	HC	MC	DR	EX[3]	HC	MC	DR	EX	HC	MC	DR	EX	HC	MC	DR	EX	HC	MC	DR	EX
I. Grasses																				
A. Cool Season																				
1. Annuals																				
Japanese brome	63	47	52	68	26	35	62	86	7	50	7	10	40	68	26	68	3	1	—	1
Little barley	13	4	5	—	5	5	3	—	7	2	—	—	18	1	4	—	1	—	—	T[4]
Sixweeks fescue	5	3	3	—	3	5	1	—	1	1	3	—	9	1	4	—	—	—	—	—
2. Perennials																				
Western wheatgrass	1	—	—	24	—	—	—	—	—	—	—	—	—	6	3	41	—	—	—	
Texas wintergrass	85	64	74	41	72	84	71	55	57	69	41	32	87	73	56	45	15	9	—	8
Texas bluegrass	—	—	—	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B. Warm Season																				
1. Annuals	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2. Perennials																				
Big bluestem	—	—	—	1	—	—	—	—	—	—	—	—	—	T	—	—	—	5	—	28
Red threeawn	5	15	15	3	7	12	19	9	26	19	36	13	6	6	5	6	38	53	—	3
Sideoats grama	18	34	2	24	8	5	68	11	18	23	63	34	2	12	43	12	75	71	—	26
Hairy grama	—	—	—	—	—	—	—	—	1	—	5	T	—	—	11	T	29	53	—	10
Texas grama	T	—	T	T	T	—	T	T	T	T	9	—	1	1	18	T	2	16	—	T
Silver bluestem	3	2	5	33	3	2	5	33	1	2	23	7	T	2	4	2	10	57	—	15
Buffalograss	76	59	58	5	76	76	40	2	69	43	32	4	80	55	46	2	52	9	—	13
Arizona cottontop	—	—	—	—	—	—	—	21	—	—	—	—	—	—	—	T	—	—	—	—
Hairy tridens	—	T	—	—	—	—	—	—	6	—	T	—	—	—	T	—	11	—	—	1
Texas cupgrass	1	—	8	31	1	18	1	8	—	T	—	53	1	29	2	32	10	4	—	7
Common curlymesquite	2	—	—	—	8	—	4	—	T	1	10	—	—	—	37	T	—	—	—	1
Halls panicum	27	5	26	T	13	7	9	2	5	7	8	T	3	4	15	T	1	1	—	T
Tumblegrass	52	24	33	1	42	32	14	1	25	11	3	7	58	24	33	2	14	1	—	1
Meadow dropseed	2	1	2	7	1	1	1	1	2	8	9	12	2	3	1	5	3	T	—	67
Sand dropseed	5	16	24	2	5	16	7	1	8	15	5	2	11	28	6	3	1	1	—	—
White tridens	22	20	16	1	26	23	6	1	17	4	3	4	29	15	18	10	9	1	—	—
Slim tridens	—	—	—	4	—	—	—	—	—	—	—	30	—	T	—	24	T	T	—	10
Vine mesquite	2	2	1	1	9	4	2	9	2	T	—	T	3	1	T	—	2	—	—	1
II. Forbs																				
A. Cool Season																				
1. Annuals																				
Southwestern carrot	1	2	7	T	2	6	4	4	2	8	1	3	3	4	1	1	1	—	—	5
Texas fillaree	—	—	—	—	—	T	—	—	7	T	—	—	—	—	T	—	1	—	—	—
Manystem evax	2	8	6	T	14	23	4	—	7	6	12	T	15	2	21	1	16	17	—	4
Three petal gaura	4	2	10	—	3	2	3	—	7	3	3	1	6	2	4	T	2	T	—	1
Redseed plaintain	15	36	29	T	60	55	22	T	37	32	13	10	27	19	27	1	37	11	—	9
Drummond skullcap	9	5	24	1	10	12	11	—	12	19	8	6	19	5	14	T	8	T	—	T
2. Perennials																				
B. Warm Season																				
1. Annuals																				
Texas broomweed	18	25	23	T	22	30	12	T	18	28	17	7	23	15	19	6	24	5	—	7
2. Perennials																				
Low wildmercury	5	1	3	1	7	1	8	1	4	T	6	1	8	3	2	3	T	T	—	—
Heath aster	1	3	6	7	1	1	2	14	T	5	12	30	3	1	3	28	2	6	—	7
Dotted gayfeather	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	—	2	13	—	5
Blackfoot	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	21	2	—	1
Yellow woodsorrel	21	1	5	T	11	T	T	T	—	3	1	T	25	1	—	T	—	—	—	—
Germander	2	33	—	—	2	5	7	2	T	T	18	7	1	6	T	3	3	T	—	T
Resindot skullcap	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	26	31	—	6
Catnip noseburn	1	—	—	19	1	—	1	35	—	4	1	1	2	5	—	3	T	—	—	—
Drummond hedeoma	—	—	—	—	—	—	—	—	—	—	T	9	—	—	—	—	1	4	—	T

[1]Th[illegible]k soil series. [2]Nukrum soil series. [3]HC and MC=yearlong continuous grazing at heavy and moderate rates of stocking, respectively. DR=deferr[illegible]rotation. EX[illegible]closure. [4]Trac[illegible]×0.5% frequency.

Japanese brome and white tridens were subdominant grasses while redseed plantain, annual broomweeds, and yellow woodsorrel were the dominant forbs. In the MC treatment the dominant grasses were Japanese brome, Texas wintergrass, and buffalograss. Subdominants were Texas cupgrass and sand dropseed. There was no dominant forb. The dominant grass in the DR treatment was Texas wintergrass. Subdominants were Japanese brome, sideoats grama, buffalograss, common curlymesquite, and tumblegrass. The dominant forb was redseed plantain. The dominant grass in the EX treatment was Japanese brome. Subdominants were western wheatgrass, Texas wintergrass, and Texas cupgrass. The dominant forb was heath aster.

Rocky Hills Range Site

The dominant grasses in the HC treatment were sideoats grama and buffalograss with subdominants of red threeawn and hairy grama (Table 3). The dominant forbs were redseed plantain and resindot skullcap. In the MC treatment the dominant grasses were red threeawn, sideoats grama, hairy grama, and silver bluestem. There were no subdominant grasses. The dominant forb was resindot skullcap. No rocky hills range site was available for study in the DR treatment. The dominant grass in the Ex treatment was meadow dropseed. Subdominants were big bluestem and sideoats grama. There were no dominant forbs in the exclosures.

Clay Flat Range Site

Texas wintergrass and buffalograss were dominant grasses in the HC treatment (Table 3). Major subdominants were Japanese brome, tumblegrass, and white tridens. The dominant forb was redseed plantain. Texas wintergrass and buffalograss were also the dominant grasses in the MC treatment. Subdominants were Japanese brome and tumblegrass. Redseed plantain was the dominant forb. The dominant grasses in the EX treatment were Japanese brome, Texas wintergrass, and sideoats grama. Buffalograss was a subdominant. There were no dominant forbs. The dominant grasses in the exclosure were Japanese brome and Texas wintergrsass. Silver bluestem was a subdominant. The dominant forb was catnip noseburn.

Loamy Bottomland Range Site

Dominant grasses in the HC treatment were Japanese brome, Texas wintergrass, buffalograss, and tumblegrass (Table 3). Halls panicum was a subdominant grass. There was no dominant forb. In the MC treatment, the dominant grasses were Texas wintergrass and buffalograss with subdominants of Japanese brome and sideoats grama. The dominant forbs were redseed plantain, annual broomweeds, and germander. Japanese brome, Texas wintergrass, and buffalograss were the dominant grasses in the DR treatment. Subdominants were Halls panicum and tumblegrass. The dominant forbs were redseed plantain and drummond skullcap. Japanese brome was the dominant grass in the EX treatment with a subdominance of Texas wintergrass, silver bluestem, and Texas cupgrass. There was no dominant forb.

Forage Production

Estimated ANPP varied significantly ($P < 0.05$) among range sites but not grazing treatments. Averaged across treatments, estimated ANPP on the rocky hills range site was 2,220 kg/ha, which was significantly less than the 3,125 and 3,517 kg/ha estimated for the clay loam and loamy bottomland sites, respectively (Table 4).

Clay Loam Range Site

Total forage production did not vary significantly among grazing treatments although grazing treatment did affect the relative composition of the warm-season grasses in that shortgrasses dominated the HC treatment, midgrasses dominated the exclosures, and composition in the MC treatment was a mixture of short and midgrasses (Table 4). Warm-season grass production in the HC treatment was dominated by buffalograss (810 kg/ha). Production in the EX treatment was dominated by sideoats grama (775 kg/ha), Texas cupgrass (695 kg/ha), and slim tridens (1,065 kg/ha). Dominant warm-season grass species in the MC treatment were buffalograss (350 kg/ha), red threeawn (320 kg/ha), and meadow dropseed (230 kg/ha). Differences among treatments in the relative productivity of annual grasses, Texas wintergrass, and annual and perennial forbs were not significant.

Rocky Hills Range Site

Neither total forage production nor relative composition by functional group varied significantly among grazing treatments (Table 4). Some differences did occur among treatments in the species composition of the warm-season grass component in that the HC treatment was dominated by sideoats grama (410 kg/ha), the MC treatment by sideoats grama (640 kg/ha) and silver bluestem (220 kg/ha), and the EX treatment by sideoats grama (130 kg/ha), meadow dropseed (570 kg/ha), slim tridens (130 kg/ha), and big bluestem (160 kg/ha).

Loamy Bottomland Range Site

Total forage production did not vary significantly among grazing treatments although significant differences did occur among grazing treatments in the relative contributions of the warm-season short and midgrasses to the total (Table 4). Response was quite similar to that on the clay loam site in that shortgrasses dominated the HC treatment, midgrasses dominated the EX treatment, and the MC treatment was dominated by a mixture of short and midgrasses. The dominant warm-season species in the HC treatment were buffalograss (805 kg/ha) and sideoats grama (235 kg/ha). The dominant species in the MC treatment were sideoats grama (720 kg/ha) and buffalograss (560 kg/ha). The dominant species in the EX treatment were silver bluestem (1,140 kg/ha), sideoats grama (720 kg/ha), Texas cupgrass (430 kg/ha), and vine-mesquite (340 kg/ha).

Discussion

Close examination of the three data sets utilized in this study indicated response of the various species/species groups varied over time as a function of soil series, range site, grazing treatment, and sampl-

TABLE 4. FUNCTIONAL GROUP COMPOSITION (PERCENT) AND ESTIMATED ANPP (KG/HA) DURING 1982 FOR THREE RANGE SITES AND THREE GRAZING TREATMENTS

	Loamy Bottomland			Clay Loam			Rocky Hill		
Species Group	HC[1]	MC	EX	HC	MC	EX	HC	MC	EX
Cool-Season Grasses									
Annual grasses	23_{a}[2]	23_{a}	16_{a}	4_{a}	17_{ab}	4_{ac}	0	0	1
Perennial grasses[3]	26_{a}	11_{a}	11_{ab}	13_{ab}	22_{ab}	7_{ac}	1	5	1
Warm-Season Grasses									
Shortgrasses	37_{a}	20_{a}	1_{bd}	40_{b}	15_{bc}	2_{c}	12	11	4
Midgrasses	11_{ab}	28_{a}	69_{c}	9_{ab}	22_{b}	74_{d}	56	69	55
Tallgrasses	—	—	—	—	—	—	0	0	21
Forbs									
Annual forbs	2_{be}	13_{abe}	0_{de}	34_{ab}	21_{b}	5_{bc}	23	5	5
Perennial forbs	1_{b}	6_{ab}	3_{abd}	0_{ab}	3_{b}	8_{bc}	8	10	13
Total (kg/ha)	3,285	3,110	4,155	2,640	2,940	3,795	1,850	2,505	2,305

[1]HC and MC = yearlong continuous grazing at heavy and moderate rates of stocking, respectively. DR = deferred rotation. EX = exclosures.

[2]Means followed by different letters within rows and columns within range site are significantly different at $P < 0.05$.

[3]Texas wintergrass was only species.

ing method; however, the variation attributed to sampling method was concluded to be of less magnitude than that attributed to either soil series, range site, or grazing treatment. Based on this conclusion, seven species/species groups were identified as key indicators of range condition and range condition trends at the Texas Experimental Ranch. The seven indicators were Texas wintergrass, buffalograss/common curlymesquite, tumblegrass, white tridens, slim tridens, big bluestem, and forbs.

Texas wintergrass is a dominant species on the deep clay and clay loam soils. Frequency data from 1960 through 1978 showed Texas wintergrass declined on the clay loam, clay flat, loamy bottomland, shallow, and deep redland soils regardless of grazing treatment. Rate of decline was greatest in the EX treatment. The decline in the grazed treatments, particularly the HC treatment, was presumably related to a reduction in standing crop as a result of livestock consumption. The decline in the EX treatment was presumably caused by a reduction in plant density. The 1981-82 frequency data (Table 3) and the 1982 ANPP estimates (Table 4) strongly support these explanations.

These explanations also tend to explain interpretive differences between this study and a similar study by Kothmann et al. (1978). Based on the 1960-76 point frame data and 1970 and 1972 standing crop data, they concluded that Texas wintergrass had declined to a greater extent in the HC treatment than the MC treatment on rolling hills and deep upland range sites. Although these sites have been subsequently reclassified as either clay loam, clay flat, and/or shallow range sites, little evidence was found in their data set to support their conclusion if the data were examined in light of our explanation for the differences among treatments in quantity of Texas wintergrass. Furthermore, basal cover data collected in 1977 from several clay flat range sites located in these same treatments also indicated Texas wintergrass was a dominant species regardless of grazing intensity (Wood and Blackburn, 1984).

Based on the 1981-82 frequency data (Table 3), the 1982 ANPP estimates, and personal observation, it was concluded that the buffalograss/common curlymesquite complex monitored from 1960 through 1978 was predominantly buffalograss. Thus, it is concluded that buffalograss is a dominant or subdominant species on essentially all range sites in the grazed treatments. The 1960-78 trend data suggested the response of buffalograss over time on most range sites was similar to Texas wintergrass in that it generally declined with the rate of decline greatest in the EX treatment. However, the response of buffalograss since 1960 to differences in grazing intensity was more clearly definable than that for Texas wintergrass in that it is now a dominant species in the HC treatment, a subdominant in the MC and DR treatments, and a minor species in the exclosures. This conclusion is strongly supported by the findings of Kothmann et al. (1978), and Wood and Blackburn (1984).

Species specific trend data for tumblegrass, white tridens, slim tridens, and big bluestem were not available from the 1960-78 frequency data. Based on the 1981-82 frequency data and 1982 ANPP data, tumblegrass and white tridens acted as increaser species on the loamy bottomland, clay flat, clay loam, and rocky hills range sites (Table 3). Slim tridens was identified as a decreaser species on the clay loam and rocky hills range sites because it only occurred in appreciable amounts in the EX treatment. Likewise, big bluestem was essentially restricted to the rocky hills site located in the EX treatment.

Although frequency of forbs tended to increase over time in all treatments except the HC, rate and extent of increase was greatest in the EX treatment regardless of range site. This is in agreement with the findings of Kothmann et al. (1978). Indicator species, however, varied among treatments and range sites (Table 3). Important increasers were redseed plantain, Texas broomweed, blackfoot, yellow woodsorrel, and resindot skullcap. Important decreasers were heath aster and catnip noseburn.

The response of several grass species over time varied little among

grazing treatments and/or range sites. Red threeawn tended to increase on all range sites regardless of grazing treatment while the responses of sideoats grama, silver bluestem, and sand dropseed varied among range sites and grazing treatments with few definable trends apparent. Significant amounts of sideoats grama were found on essentially all range sites in all grazing treatments. Little evidence was found in these analyses that would support the conclusion of Kothmann et al. (1978) that both red threeawn and sideoats grama had increased more in the MC than the HC treatment.

The response of annual grasses, particularly Japanese brome, to grazing treatment varied among range sites. The lack of definite trend information over time supports the concept that quantity of annual grasses within a year is closely linked to climatic factors (Kothmann et al. 1978). The 1981-82 frequency data, however, suggested Japanese brome acted as a decreaser on the clay flat range site and was of minor importance on the rocky hills range site regardless of grazing treatment (Table 3). Response of Japanese brome on the clay flat range site agrees with the findings of Wood and Blackburn (1984).

Summary and Conclusion

The two major factors governing delineation of range sites within a geographical region are soil type and slope. The three dominant range sites at the ranch are loamy bottomland, clay loam, and rocky hills. The loamy bottomland and rocky hills sites encompass the extreme end points of the soil type/slope continuum at the ranch. The clay loam site is located near the midpoint of the continuum and the remaining seven range sites (Appendix 6) are located at various points along the continuum between the clay loam site and either the loamy bottomland or the rocky hills site. Summarization of the results of this study relative to these three specific range sites is indicative of the long-term ecological response of the entire vegetative complex of the ranch relative to grazing intensity.

Loamy Bottomland

Buffalograss is the major increaser species on this site in terms of relative (frequency) and absolute (ANPP) abundance. Other perennial grasses that will increase are Texas wintergrass, white tridens, Halls panicum, and tumblegrass. Major decreasers are silver bluestem, Texas cupgrass, and vine-mesquite. Relative abundance of sideoats grama tends to remain constant with increasing grazing intensity while absolute abundance will decline. Abundance of annual grasses appears to remain relatively constant. Forbs are not a major component of the vegetation on this site regardless of grazing treatment although relative abundance of yellow woodsorrel tends to increase. ANPP in 1982 (an "average" year) averaged 3,517 kg/ha across all grazing treatments and ranged from 4,155 kg/ha in the EX treatment to 3,198 kg/ha in the HC and MC treatments.

Clay Loam

Buffalograss is the major increaser species on this site. Other perennial grasses that tend to increase in abundance are Texas wintergrass, tumblegrass, and white tridens. Relative abundance of sideoats grama will tend to remain constant although absolute abundance may decline. Both Texas cupgrass and slim tridens will decrease. The relative abundance of annual grasses will vary among grazing treatments as no discernible trends were apparent. Forbs are an important component of this vegetation complex, particularly in the grazed treatment. Increaser forbs are redseed plantain, yellow woodsorrel, Drummond skullcap, and Texas broomweed, while heath aster is the major decreaser. In 1982, ANPP averaged 3,125 kg/ha and ranged from 3,795 kg/ha in the exclosure to 2,640 kg/ha in the HC treatment.

Rocky Hills

The dominant increaser on this site is sideoats grama. Secondary increasers are red threeawn, buffalograss, and white tridens. The dominant decreasers are big bluestem, meadow dropseed, and slim tridens. Annual grasses are not an important component of the vegetation on this site. Increaser forbs are manystem evax, redseed plantain, Texas broomweed, blackfoot, and germander. The dominant decreaser forb is heath aster. ANPP in 1982 varied little among grazing treatments and averaged 2,220 kg/ha.

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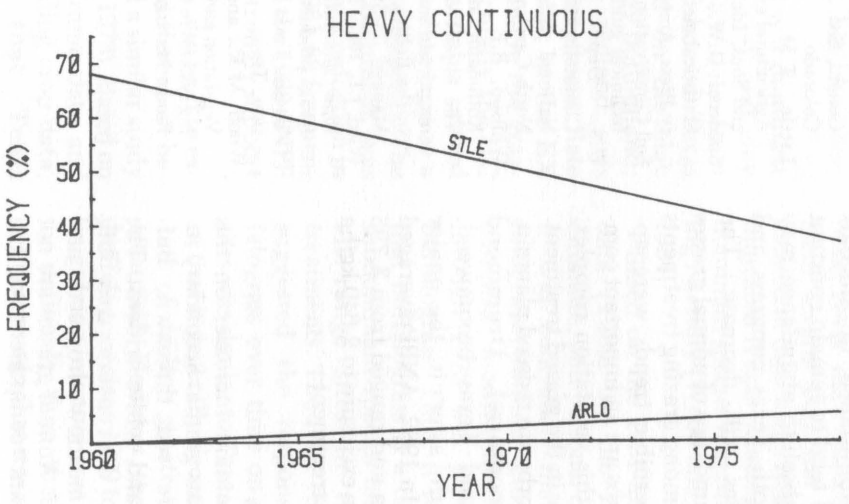
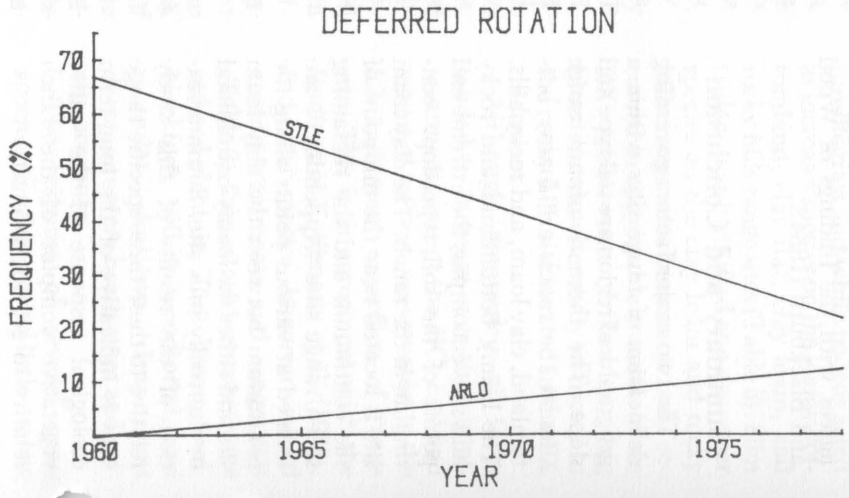
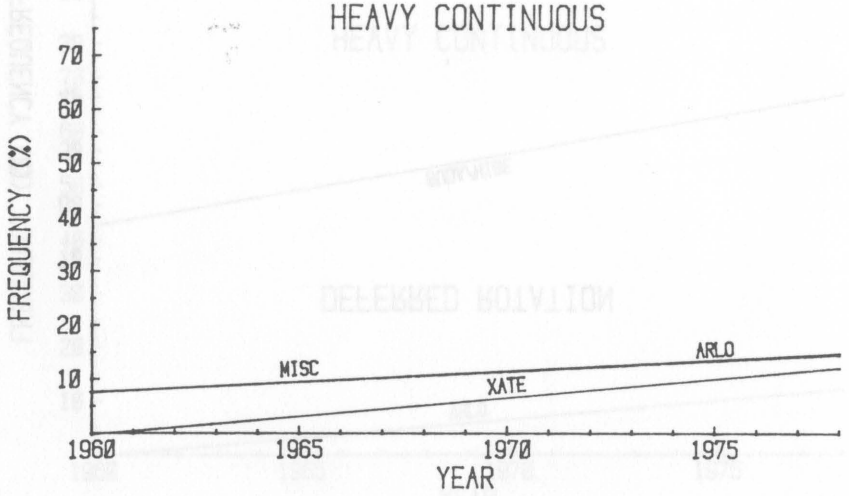
APPENDIX 1. POINT FRAME FREQUENCY DATA FOR EACH TREATMENT BY SOIL SERIES AND PLANT SPECIES.

CLAY LOAM
Valera Silty Clay






HEAVY CONTINUOUS
FREQUENCY (%)
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50
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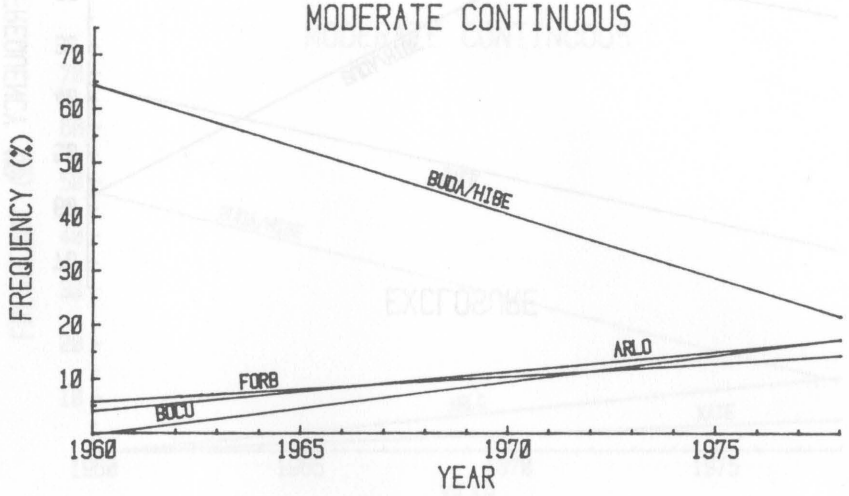
30
20
10
MISC
ARLO
XATE
1960
1965
1970
1975
YEAR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FREQUENCY (%)
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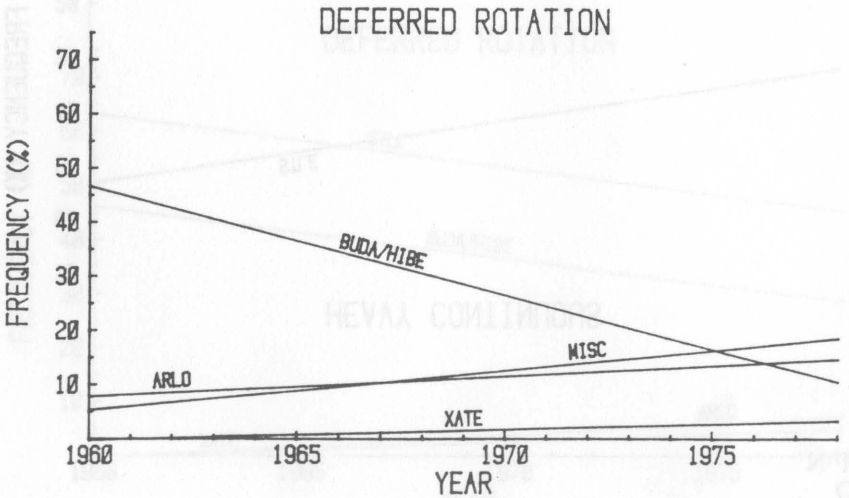
BUDA/HIBE
ARLO
FORB
BOCU
1960
1965
1970
1975
YEAR


DEFERRED ROTATION
FREQUENCY (%)
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BUDA/HIBE
MISC
ARLO
XATE
1960
1965
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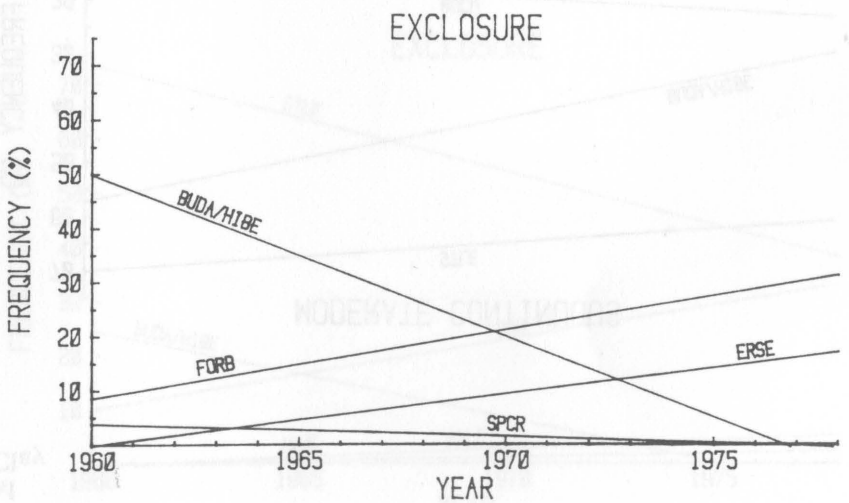
YEAR


EXCLOSURE
FREQUENCY (%)
70
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BUDA/HIBE
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ERSE
SPCR
1960
1965
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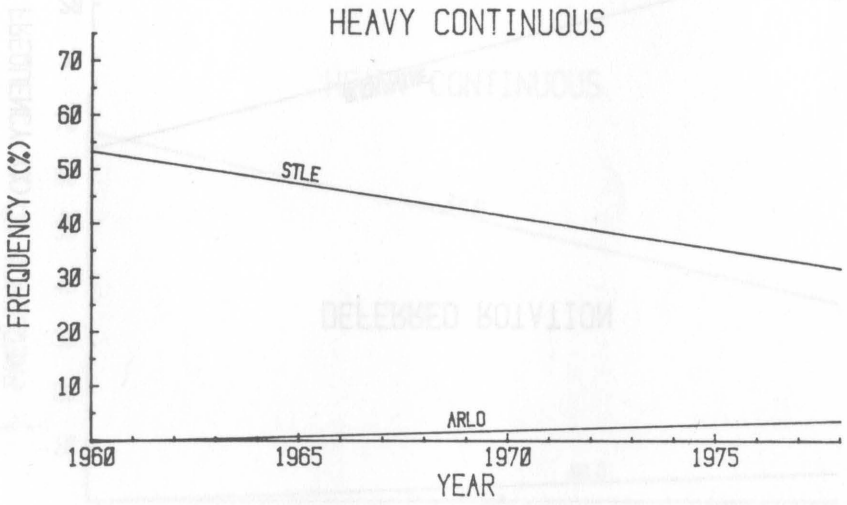
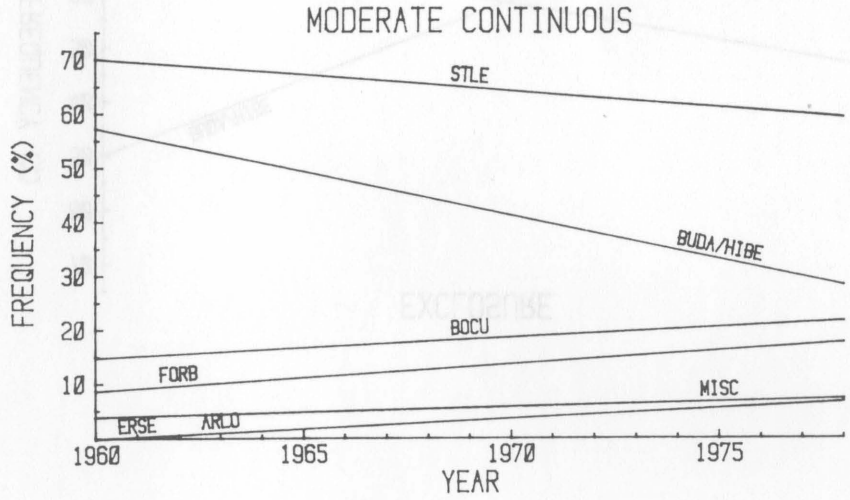
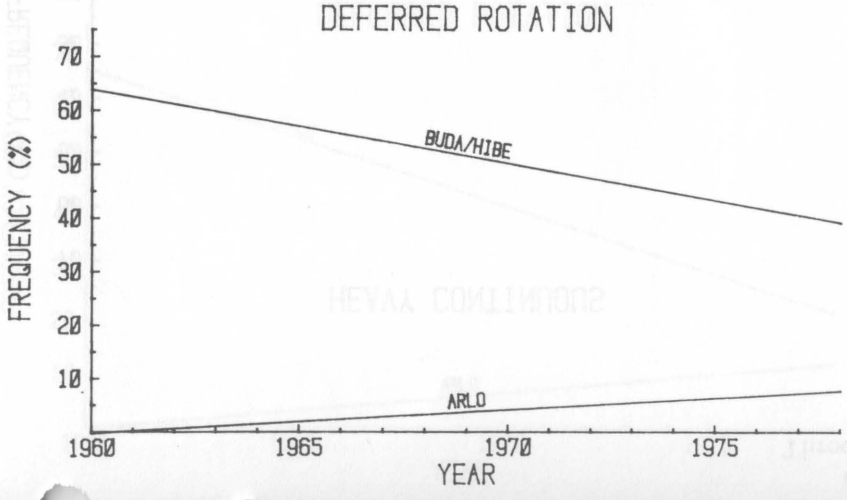
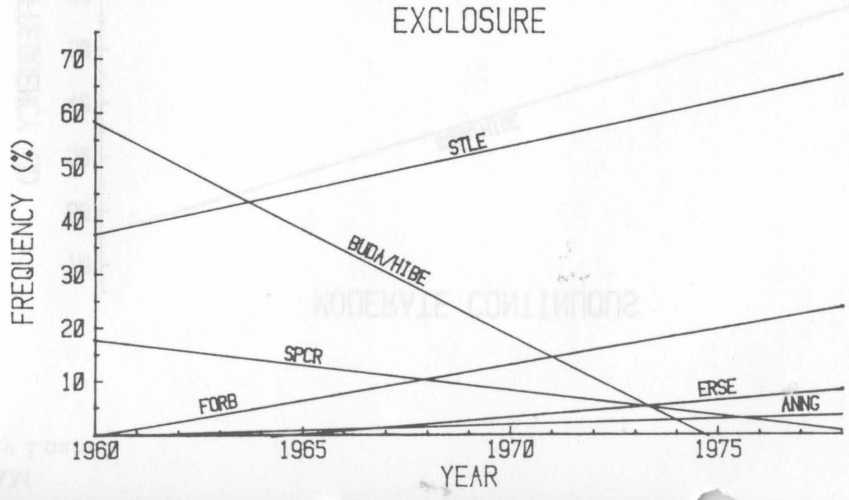
YEAR

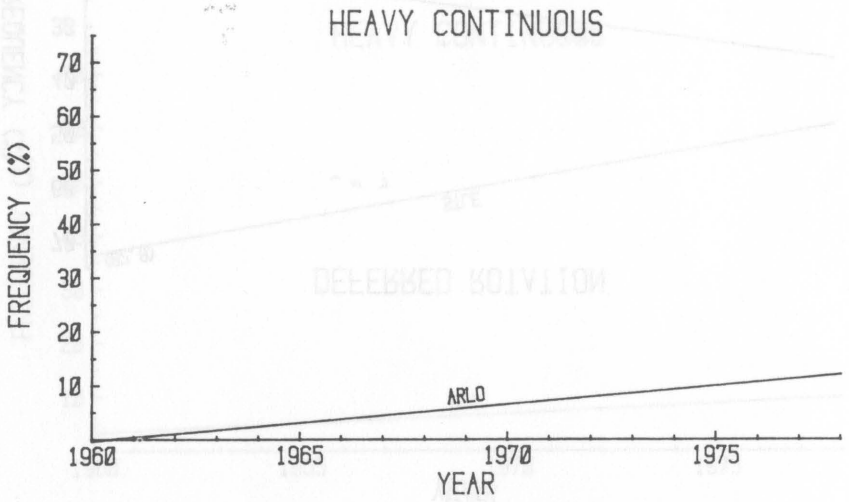
CLAY LOAM
Nukrum Silty Clay







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FREQUENCY (%)
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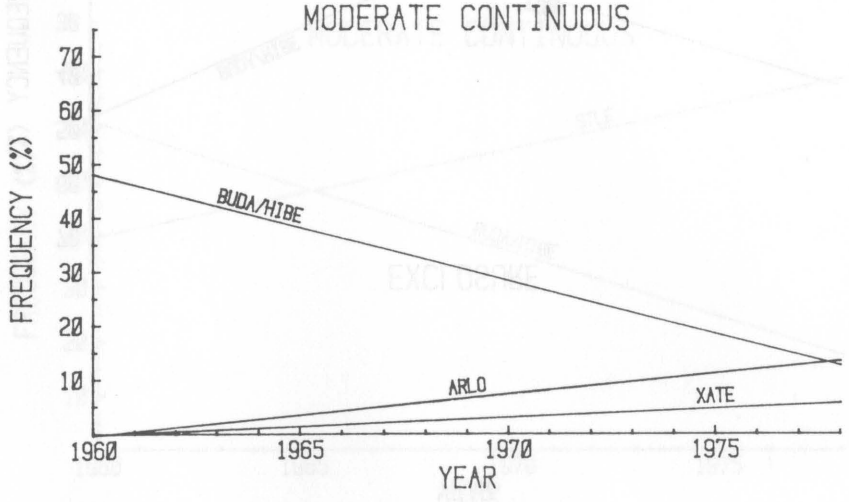
ARLO
1960
1965
1970
1975
YEAR


MODERATE CONTINUOUS
FREQUENCY (%)
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BUDA/HIBE
ARLO
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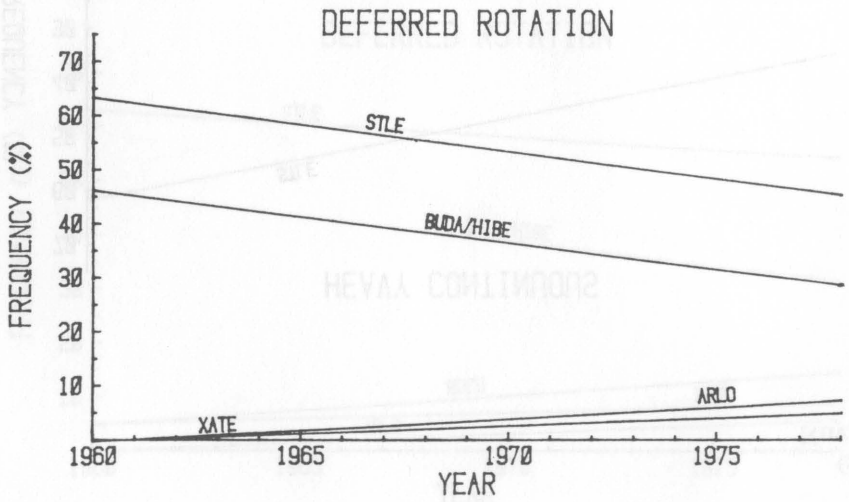
YEAR


DEFERRED ROTATION
FREQUENCY (%)
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STLE
BUDA/HIBE
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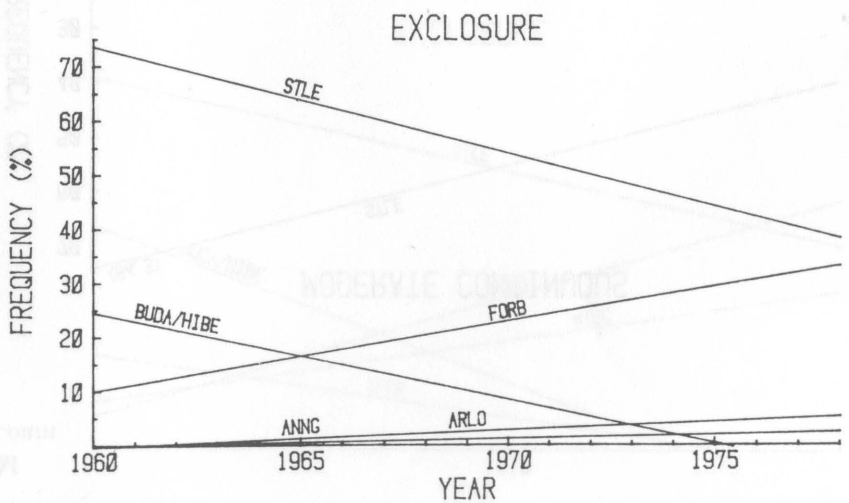
YEAR


EXCLOSURE
FREQUENCY (%)
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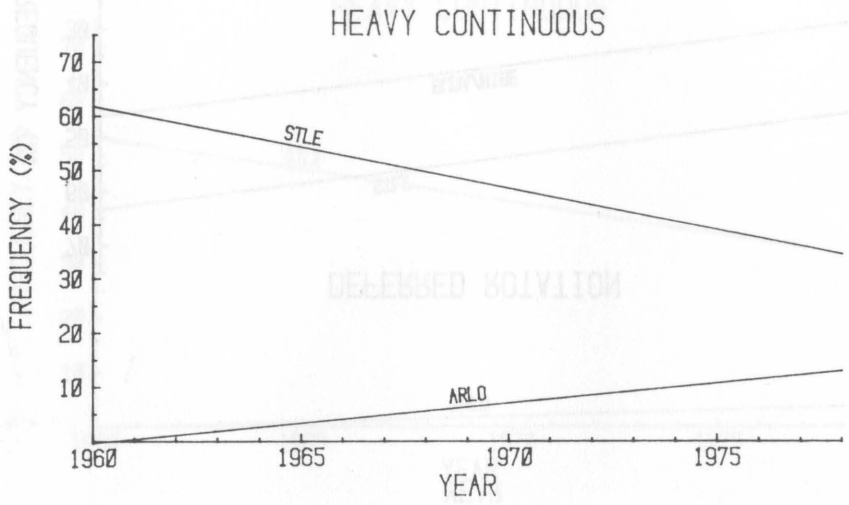
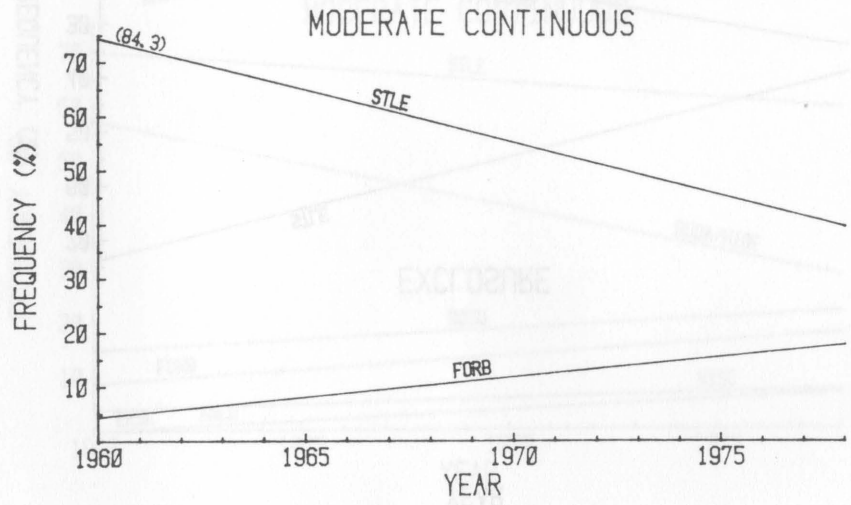
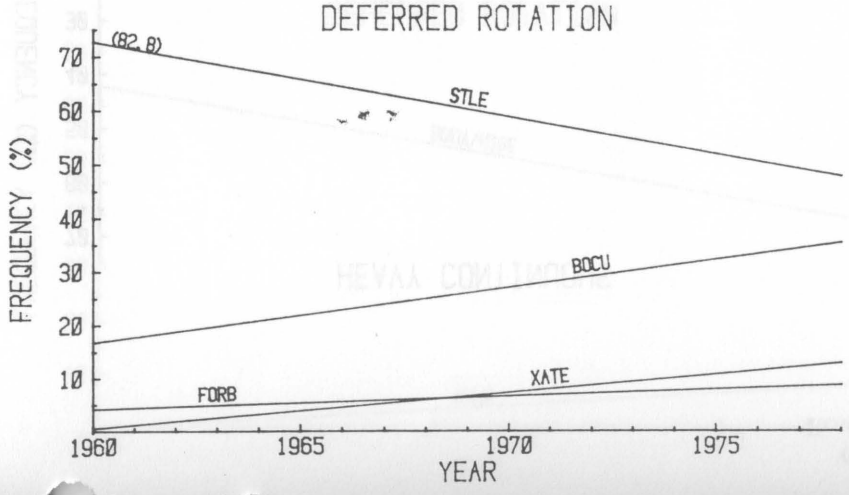
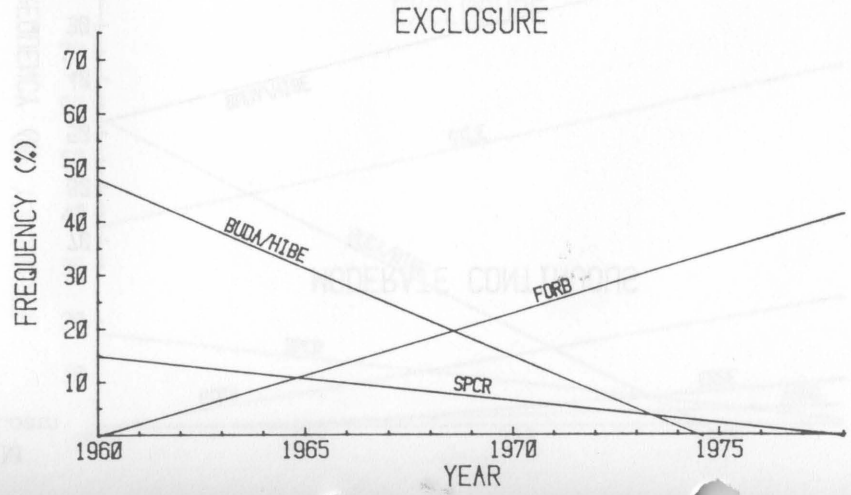
YEAR

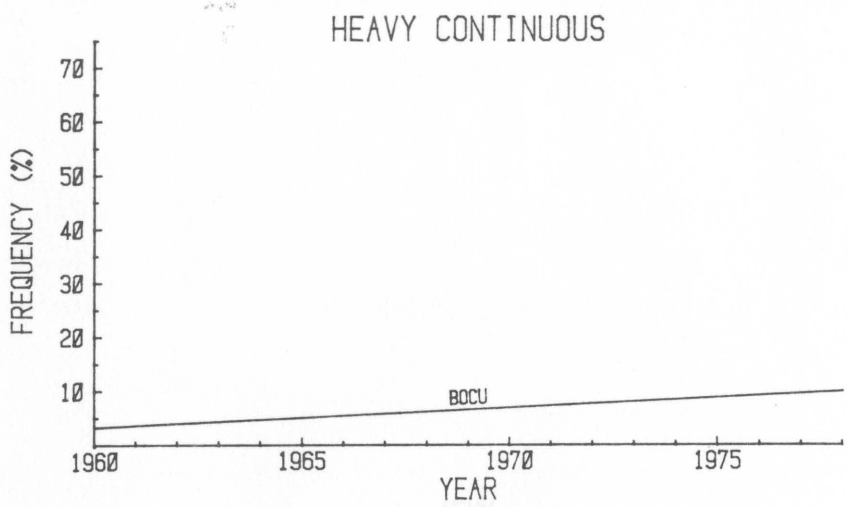
CLAY LOAM
Nuvalde Clay Loam










HEAVY CONTINUOUS
FREQUENCY (%)
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BOCU
1960
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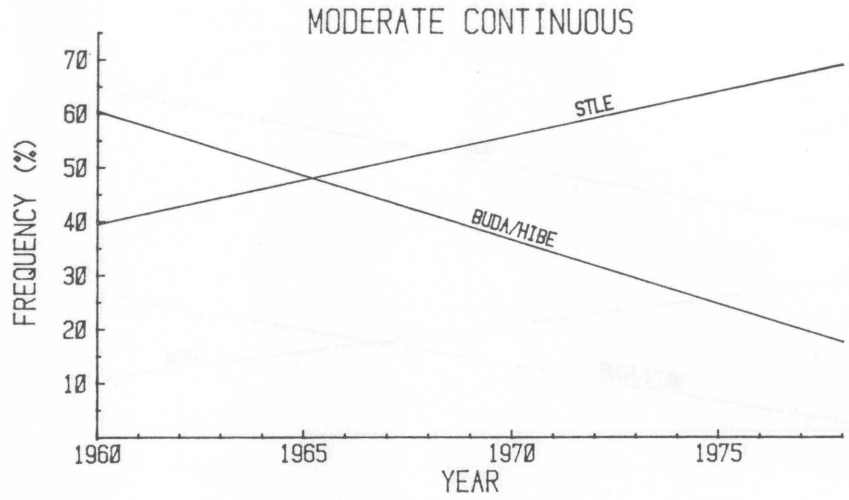
MODERATE CONTINUOUS
FREQUENCY (%)
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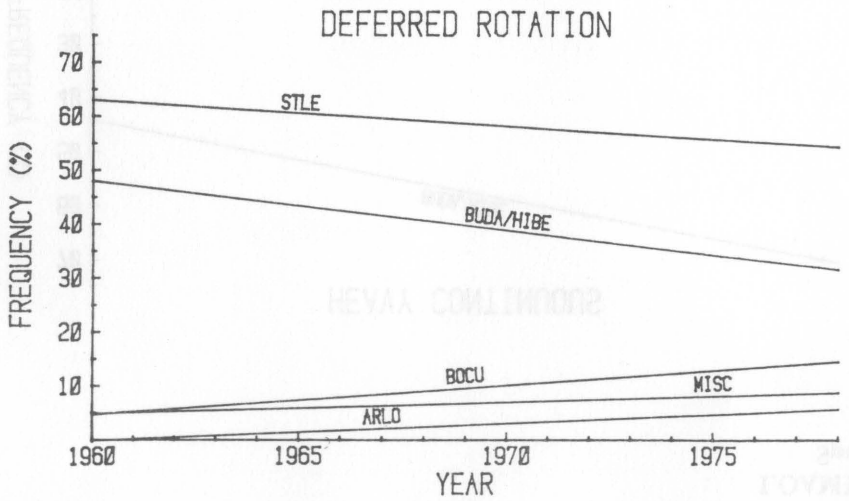
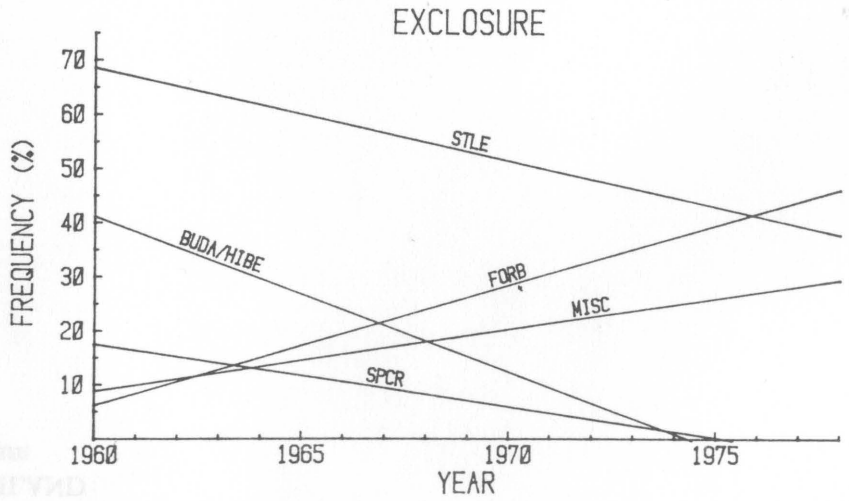
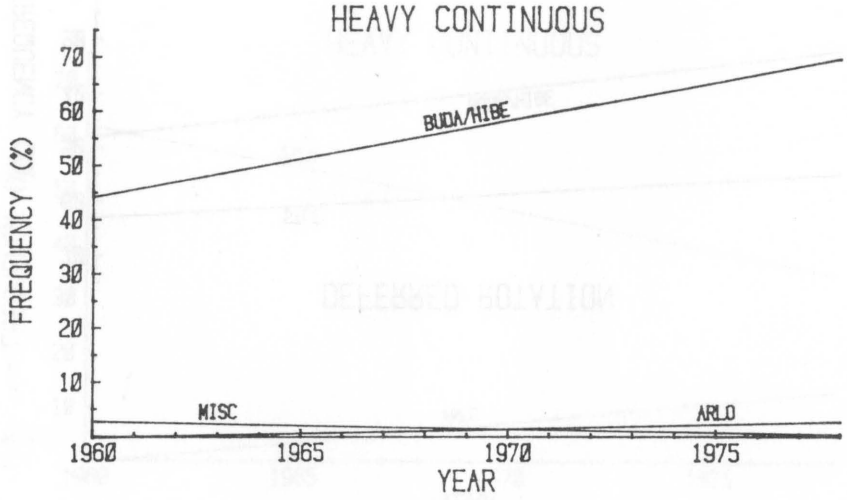
40
30
20
10
STLE
BUDA/HIBE
1960
1965
1970
1975
YEAR

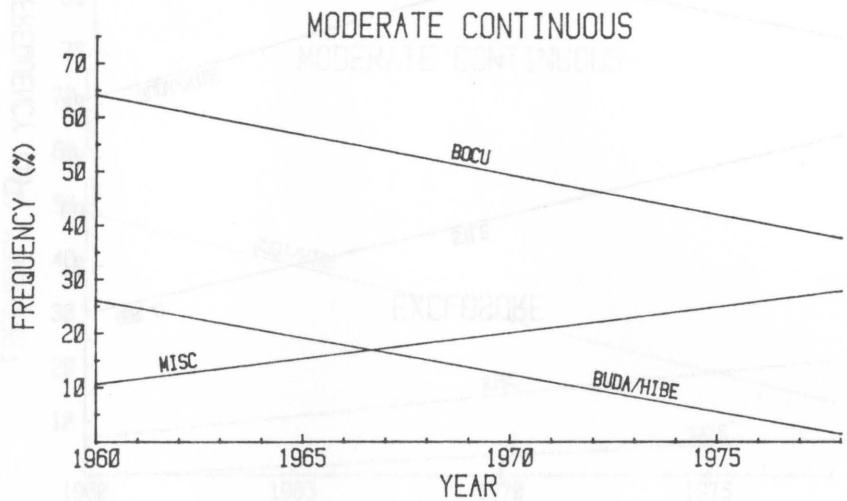

DEFERRED ROTATION
FREQUENCY (%)
70
60
50
40
30
20
10
STLE
BUDA/HIBE
BOCU
MISC
ARLO
1960
1965
1970
1975
YEAR


EXCLOSURE
FREQUENCY (%)
70
60
50
40
30
20
10
STLE
BUDA/HIBE
FORB
MISC
SPCR
1960
1965
1970
1975
YEAR

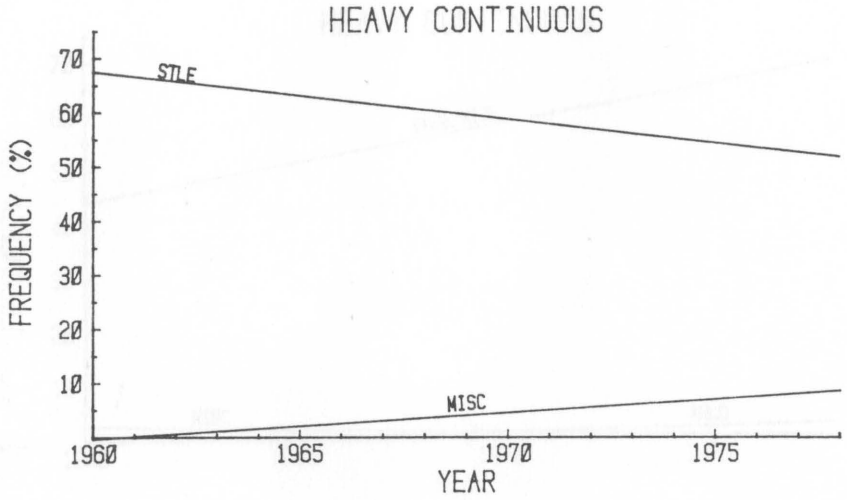
LOAMY BOTTOMLAND
Spur Clay Loam

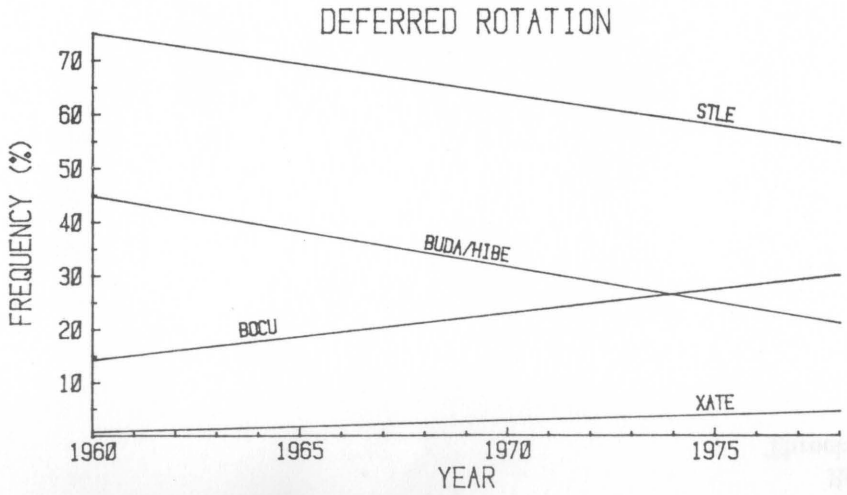


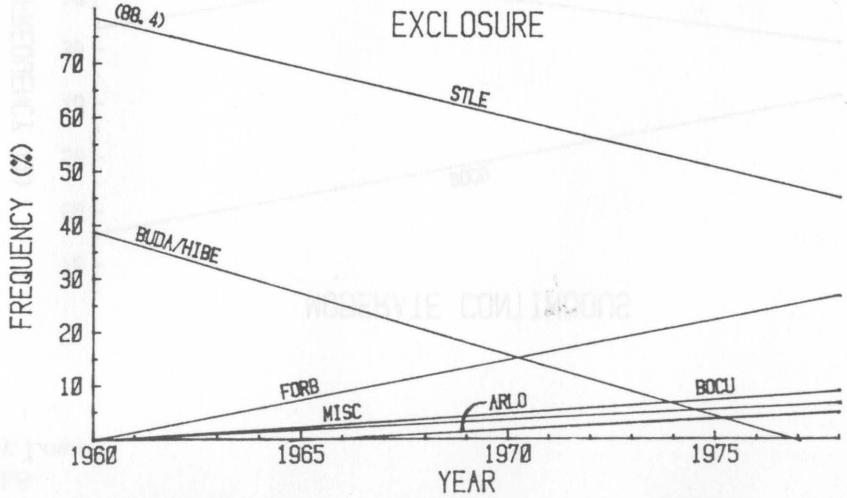
ROCKY HILLS
Throck Stoney Clay Loam

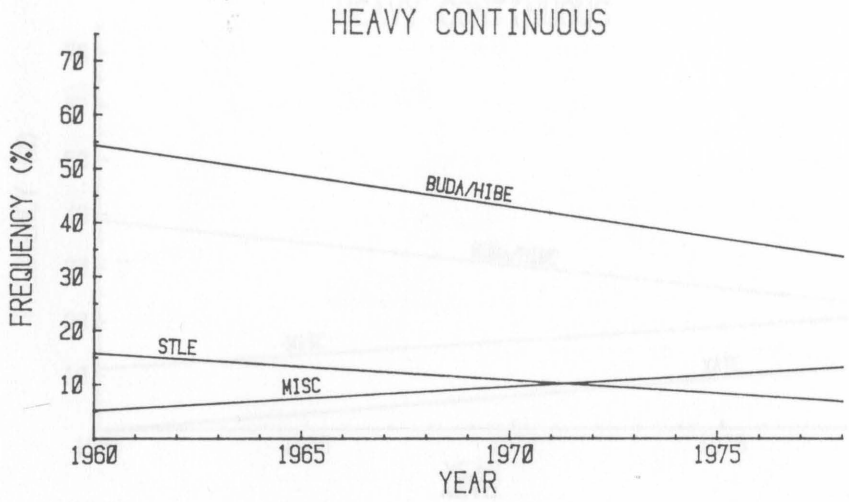


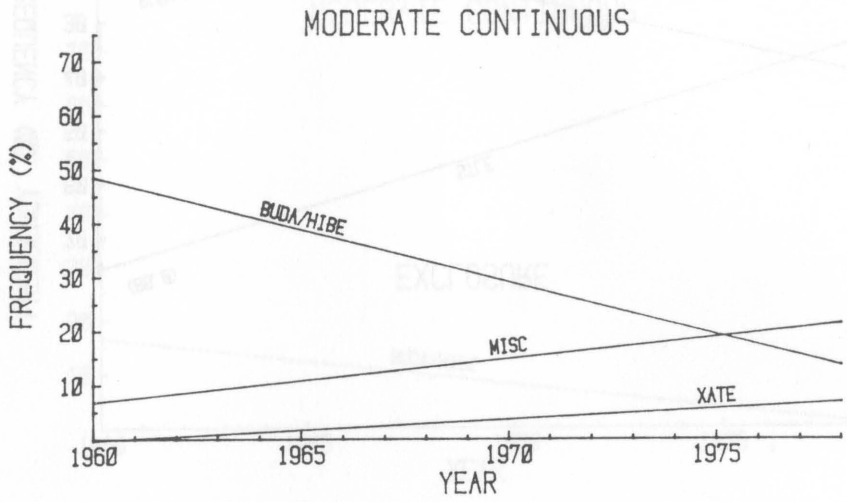
CLAY FLAT
Leeray Clay

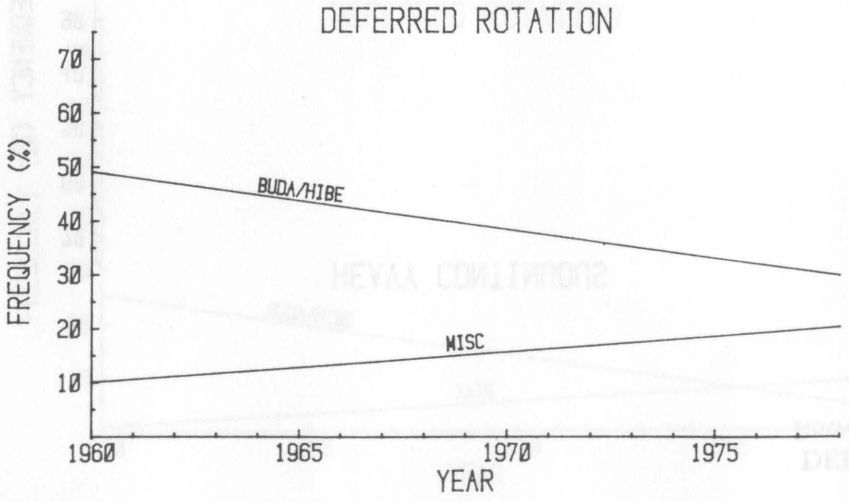


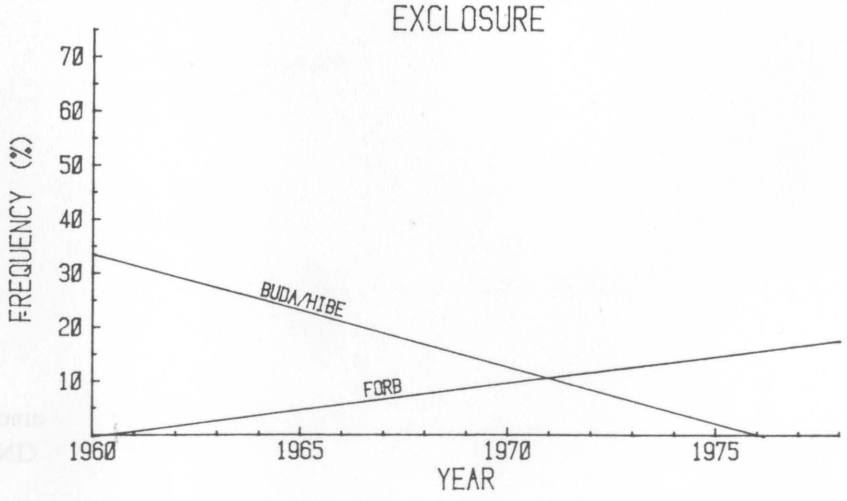


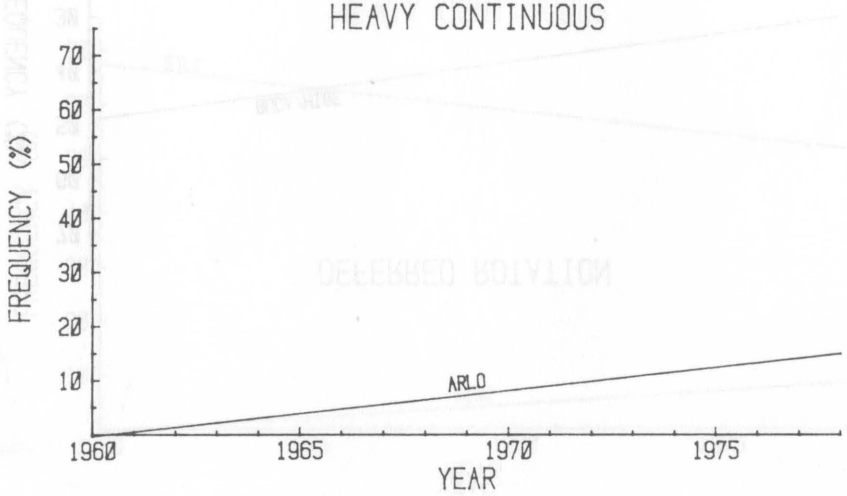


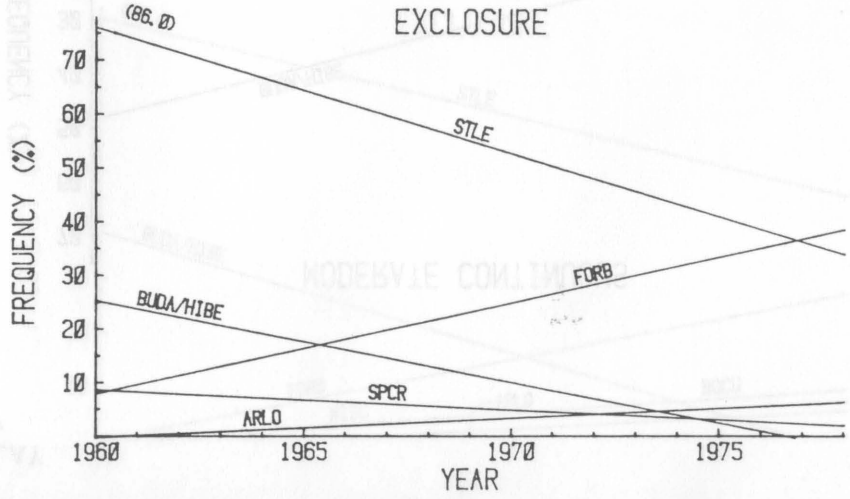

HEAVY CONTINUOUS
FREQUENCY (%)
70
60
50
40
30
20
10
BUDA/HIBE
STLE
MISC
1960
1965
1970
1975
YEAR

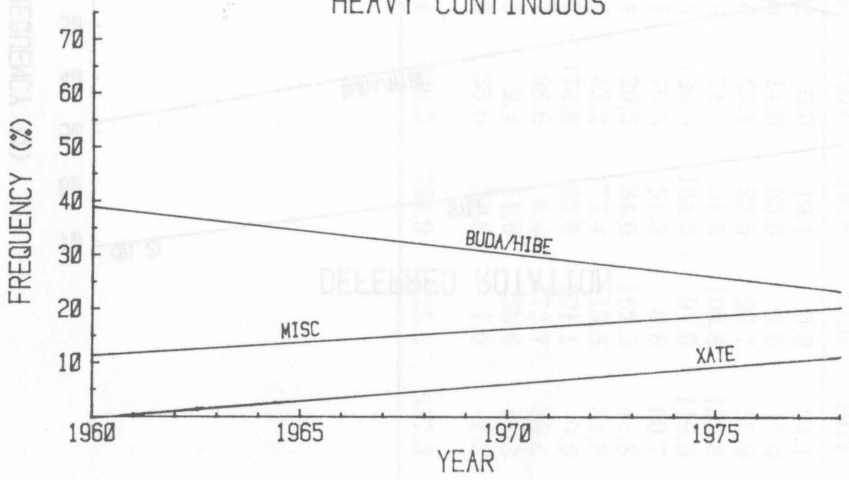

MODERATE CONTINUOUS
FREQUENCY (%)
70
60
50
40
30
20
10
BUDA/HIBE
MISC
XATE
1960
1965
1970
1975
YEAR

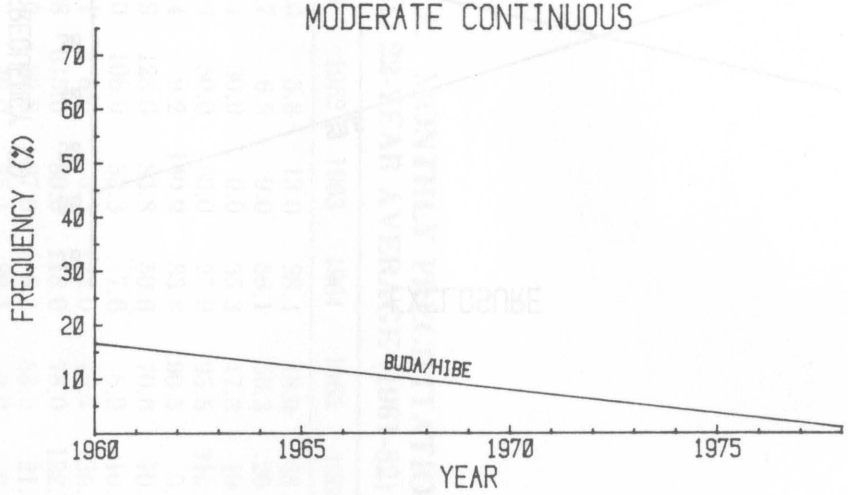

DEFERRED ROTATION
FREQUENCY (%)
70
60
50
40
30
20
10
BUDA/HIBE
MISC
1960
1965
1970
1975
YEAR

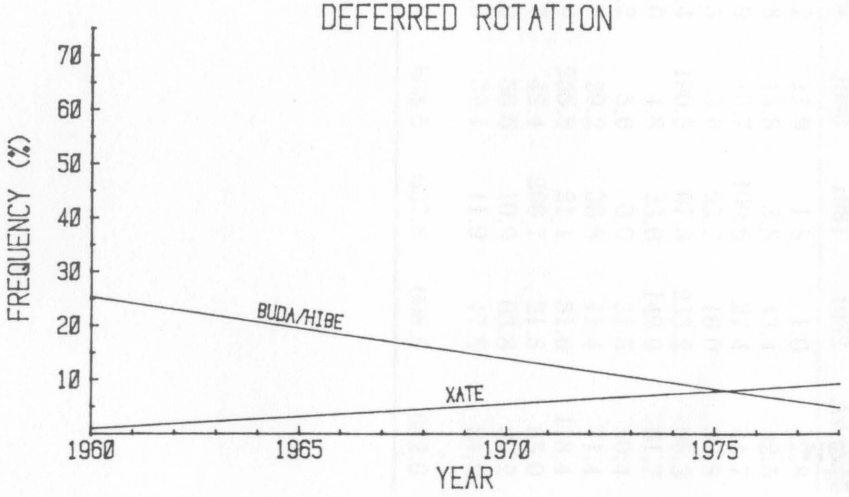

EXCLOSURE
FREQUENCY (%)
70
60
50
40
30
20
10
BUDA/HIBE
FORB
1960
1965
1970
1975
YEAR


HEAVY CONTINUOUS
FREQUENCY (%)
70
60
50
40
30
20
10
ARLO
1960
1965
1970
1975
YEAR

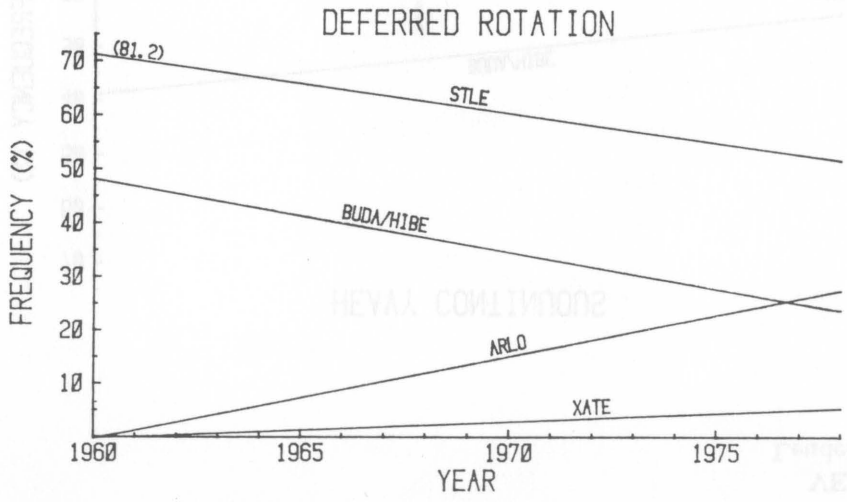

EXCLOSURE
(86.0)
STLE
FORB
BUDA/HIBE
SPCR
ARLO
FREQUENCY (%)
70
60
50
40
30
20
10
1960
1965
1970
1975
YEAR

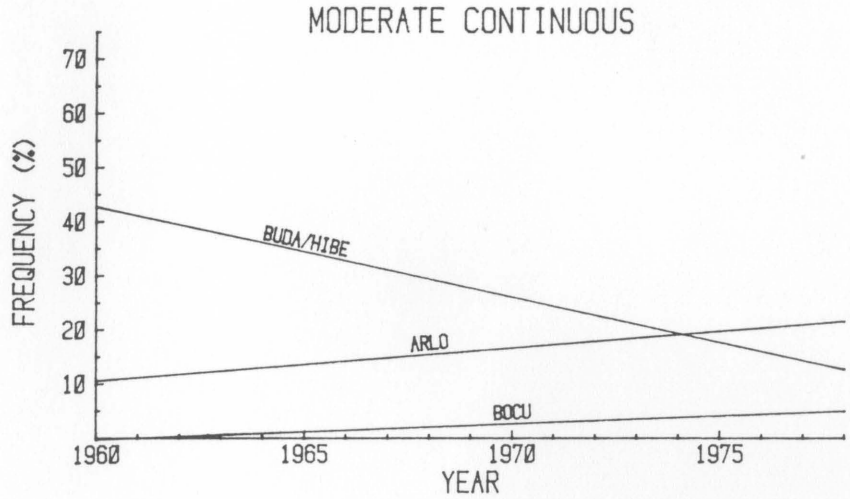

HEAVY CONTINUOUS
FREQUENCY (%)
70
60
50
40
30
20
10
BUDA/HIBE
MISC
XATE
1960
1965
1970
1975
YEAR

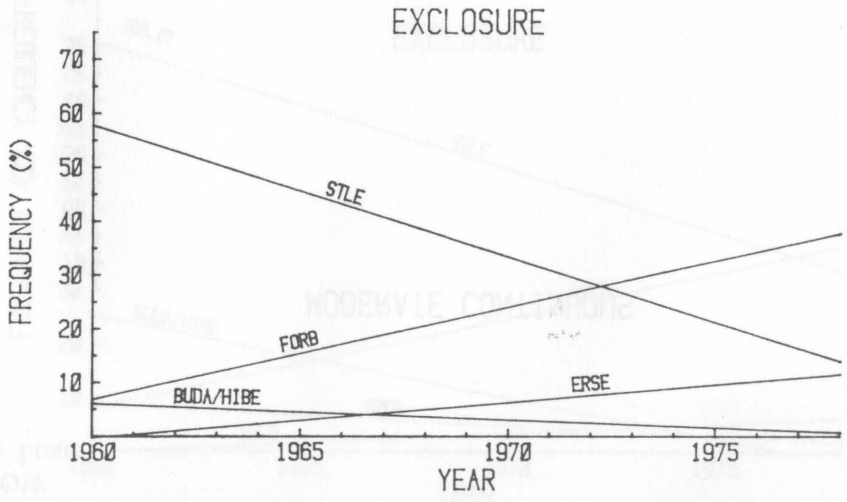

MODERATE CONTINUOUS
FREQUENCY (%)
70
60
50
40
30
20
10
BUDA/HIBE
1960
1965
1970
1975
YEAR


DEFERRED ROTATION
FREQUENCY (%)
70
60
50
40
30
20
10
BUDA/HIBE
XATE
1960
1965
1970
1975
YEAR

SHALLOW
Mereta Clay Loam







APPENDIX 2. MONTHLY PRECIPITATION (MM) AT THE TEXAS EXPERIMENTAL RANCH AND 22-YEAR AVERAGE (1961-82)

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Jan.	45.0	5.8	13.0	28.4	18.0	38.6	0.3	143.8	9.9	0.0	0.0	0.0
Feb.	46.7	6.8	9.0	56.1	36.3	20.6	11.9	39.1	62.5	46.0	22.1	14.0
Mar.	71.4	30.0	0.0	35.3	17.3	10.2	61.2	72.6	85.6	76.7	0.5	8.6
Apr.	3.0	50.0	65.0	27.9	95.5	310.9	16.5	45.7	70.9	63.8	15.0	29.0
May	26.4	9.2	140.9	83.8	190.5	0.0	77.0	165.4	106.2	96.8	54.1	108.2
June	165.9	128.0	83.8	50.6	70.6	10.4	52.8	61.7	56.9	4.8	52.6	53.6
July	161.0	106.9	39.3	7.6	8.9	10.9	136.4	127.0	0.0	0.0	17.0	52.3
Aug.	8.1	8.0	3.3	122.0	76.7	136.1	2.5	45.0	49.5	37.3	312.2	104.6
Sept.	145.8	315.0	80.0	118.0	78.0	122.2	97.8	26.7	243.1	87.6	112.3	138.4
Oct.	32.0	60.8	27.0	8.1	88.9	21.1	41.7	17.0	94.0	65.0	81.5	162.8
Nov.	93.2	46.0	55.1	89.1	0.0	6.4	21.8	88.1	18.0	5.1	19.1	39.6
Dec.	30.0	30.3	27.0	14.0	18.0	1.0	36.8	12.2	52.3	7.6	66.3	22.9
Total	828.5	795.8	541.5	642.0	698.8	688.3	556.8	844.3	848.9	490.7	752.6	734.1

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Average
Jan.	89.2	0.0	19.1	0.0	24.1	5.6	46.2	11.9	1.8	1.0	22.8
Feb.	117.9	14.0	63.0	0.0	17.0	47.0	18.8	18.8	3.8	43.4	32.5
Mar.	70.6	40.1	22.9	29.7	38.9	52.3	54.9	10.7	100.6	27.4	41.7
Apr.	38.9	71.1	31.5	100.8	127.8	21.6	18.5	3.0	93.2	16.0	59.8
May	17.8	39.9	164.6	91.9	119.9	49.8	86.4	190.5	67.3	233.2	96.3
June	70.1	78.3	51.3	6.6	60.7	38.1	82.0	4.8	23.6	149.9	61.7
July	58.4	29.5	84.6	162.3	48.8	10.2	10.2	5.6	0.0	31.5	50.4
Aug.	26.7	43.2	73.4	13.5	34.0	231.4	164.8	29.2	36.8	11.4	71.4
Sept.	121.7	176.8	122.9	201.1	9.9	78.7	0.0	255.8	21.1	51.6	118.4
Oct.	45.7	98.6	8.4	172.7	36.8	27.9	9.7	42.4	266.7	21.8	65.0
Nov.	18.5	9.4	51.6	35.6	18.3	55.9	17.0	56.6	10.9	63.8	37.2
Dec.	0.0	35.6	31.8	1.0	1.3	0.0	61.0	39.1	11.9	47.8	24.9
Total	675.4	636.3	724.9	815.3	537.5	618.5	569.5	668.5	637.8	698.8	682.0

APPENDIX 3. AVERAGE MINIMUM DAILY TEMPERATURES (°C) AT THROCKMORTON AND 23-YEAR AVERAGE (U.S. DEPT. COMMERCE 1960-1982)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Jan.	-0.6	-3.3	-5.9	-5.8	-2.0	0.6	-0.4	-1.2	-0.2	-0.1	-4.1	-1.3
Feb.	-2.0	-0.8	1.1	-1.4	-1.5	-0.6	-1.2	-0.9	-1.1	1.4	0.1	-1.5
Mar.	1.1	6.2	2.6	6.2	3.1	0.5	6.2	8.3	5.4	0.8	2.6	2.5
Apr.	11.4	9.5	10.6	15.6	12.0	12.4	10.3	14.3	9.8	11.2	10.1	9.5
May	14.0	15.1	17.7	16.7	16.7	16.5	14.7	13.8	15.2	15.2	13.3	14.2
June	21.2	18.5	18.7	20.6	19.6	19.9	19.9	20.8	19.3	19.5	18.6	20.8
July	23.7	20.3	22.2	23.4	23.4	22.8	24.0	21.6	21.2	23.2	21.6	21.9
Aug.	21.9	19.3	21.9	21.7	23.3	21.3	20.4	20.9	21.7	21.7	21.1	19.4
Sept.	17.8	16.6	18.4	18.4	18.2	18.7	17.4	16.6	15.2	17.3	18.7	16.8
Oct.	13.1	9.6	14.1	13.9	10.3	11.1	10.1	10.2	11.1	8.7	8.7	12.6
Nov.	5.5	3.0	5.8	5.6	6.3	8.4	6.7	5.6	4.2	2.9	1.3	5.4
Dec.	-1.1	-0.6	1.0	-2.7	-0.7	3.3	-2.3	-0.5	-1.3	0.4	0.7	1.7
Avg.	10.5	9.5	10.7	11.0	10.7	11.2	10.5	10.8	10.0	10.2	9.4	10.2

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Avg.
Jan.	-3.3	-2.9	-3.7	-1.1	-2.7	-5.3	-5.8	-5.3	-0.8	-0.8	-3.1	-2.4
Feb.	-0.4	-0.8	0.1	-2.1	3.9	1.8	-3.9	-2.7	-1.7	0.7	-1.5	-0.6
Mar.	6.1	6.4	8.1	3.1	5.8	4.9	3.0	5.3	2.0	6.4	5.9	4.5
Apr.	11.7	7.6	9.9	8.4	11.6	10.3	12.2	9.6	7.4	12.4	9.5	10.8
May	14.7	13.6	16.7	13.7	12.1	16.9	15.8	13.3	17.1	13.8	15.5	15.1
June	19.6	17.8	17.9	18.5	19.0	20.1	20.9	18.2	21.8	19.7	18.7	19.5
July	20.7	21.5	20.9	19.9	20.2	21.7	23.8	21.8	23.0	22.7	21.4	22.0
Aug.	20.6	20.2	19.9	20.3	20.6	22.4	21.0	20.1	22.6	20.8	21.8	21.1
Sept.	18.3	17.4	13.8	13.7	16.8	19.3	19.3	15.7	18.7	17.4	17.1	17.3
Oct.	10.8	11.9	11.3	9.9	7.0	11.3	10.7	10.8	10.7	12.7	10.1	10.9
Nov.	1.7	7.4	4.1	4.8	1.2	5.4	6.2	1.4	4.6	5.3	4.6	4.6
Dec.	-2.4	-1.8	-0.6	-0.2	-1.8	-0.2	-2.1	0.1	1.5	0.1	1.4	-0.4
Avg.	9.8	9.9	9.9	9.1	9.5	10.7	10.1	9.0	10.6	10.9	10.1	10.2

APPENDIX 4. AVERAGE MAXIMUM DAILY TEMPERATURES (°C) AT THROCKMORTON AND 23-YEAR AVERAGE (U.S. DEPT. COMMERCE 1960-1982)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Jan.	11.4	11.1	9.3	9.9	14.6	14.6	9.1	16.1	9.7	14.3	10.3	15.2
Feb.	11.8	14.7	19.9	15.5	12.5	13.2	12.3	15.4	11.7	14.2	15.2	15.6
Mar.	14.2	20.8	17.9	22.6	19.5	13.2	21.1	24.8	17.1	13.5	15.3	20.9
Apr.	25.9	24.9	23.2	27.8	27.0	26.3	24.1	27.9	22.8	24.9	24.0	25.7
May	28.6	29.6	32.0	29.7	30.8	27.3	28.1	28.9	27.9	27.6	27.2	30.9
June	35.6	31.0	32.0	33.1	33.6	32.2	33.2	34.3	31.9	32.0	32.7	35.1
July	35.0	33.3	35.7	37.5	38.6	37.3	37.2	34.3	33.6	38.1	36.4	36.3
Aug.	35.2	35.1	37.7	38.0	36.6	35.6	33.3	35.3	35.1	36.1	36.6	30.8
Sept.	33.3	29.8	30.1	32.8	30.0	33.1	28.5	27.4	30.4	29.2	30.9	28.3
Oct.	26.2	25.6	27.6	30.7	24.9	24.6	23.8	26.0	27.8	21.4	23.2	24.7
Nov.	20.1	15.6	18.1	19.9	19.4	22.2	21.7	17.5	18.2	18.6	17.9	18.5
Dec.	10.0	11.9	13.8	9.3	14.1	15.1	13.0	12.3	13.9	14.8	17.8	14.2
Avg.	23.9	23.6	24.8	25.6	25.1	24.6	23.8	25.0	23.3	23.7	24.0	24.7

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Avg.
Jan.	12.8	8.7	11.9	11.2	14.0	6.9	6.6	4.5	11.7	12.9	14.1	11.4
Feb.	16.3	12.9	18.7	12.0	20.8	16.4	6.6	11.4	13.6	14.9	12.2	14.3
Mar.	23.8	20.3	24.2	17.5	21.4	20.9	19.2	19.1	19.1	17.8	20.2	19.3
Apr.	28.3	20.2	26.4	22.2	24.9	23.2	28.0	23.1	25.1	25.2	23.3	25.0
May	27.4	28.6	31.5	27.8	26.3	28.0	30.6	26.3	28.0	27.6	27.2	28.6
June	34.1	32.4	33.9	31.9	32.6	34.1	34.6	30.8	35.2	32.4	31.2	33.0
July	34.3	35.1	36.3	33.4	31.7	36.3	38.9	34.6	39.7	36.7	33.6	35.8
Aug.	33.7	34.8	32.6	34.0	35.4	36.2	33.0	34.2	37.2	34.6	35.9	35.1
Sept.	30.2	29.3	25.3	28.1	28.6	35.8	30.3	32.1	31.7	32.2	32.0	30.4
Oct.	24.6	25.5	24.4	26.2	19.8	27.0	25.8	29.4	25.1	23.9	26.1	25.4
Nov.	12.8	20.3	17.3	19.9	13.8	20.2	17.5	16.9	16.7	20.4	18.2	18.4
Dec.	12.1	16.1	11.8	15.4	13.5	16.4	12.6	14.3	15.1	14.6	13.1	13.7
Avg.	24.2	23.7	24.5	23.3	23.6	25.1	23.6	23.1	24.8	24.4	23.9	24.2

APPENDIX 5. DESCRIPTION OF DOMINANT RANGE SITES AND SOIL SERIES FOLLOWING SOIL CONSERVATION SERVICE (1984) GUIDELINES

Clay Loam Range Site

Site occurs on nearly level to gently sloping upland plains with slopes rarely in excess of 3 percent. The climax plant community consists of a mixture of short and midgrasses. Sideoats grama is considered the dominant climax species with lesser amounts of blue grama, vine-mesquite, Arizona cottontop, and buffalograss. Woody plants are not considered to be a significant component of the climax vegetation. Estimated total annual herbage yields vary from 1,700 to 3,400 kg/ha depending upon rainfall and range condition.

Valera Soil Series. The Valera series is a member of the fine, montmorillonitic, thermic family of Petrocalcic Calciustolls. These soils have thick, dark grayish-brown A horizons of crumbly calcareous silty clay which grade through brown silty clay to horizons of cemented calcium carbonate ($CaCo^3$). They are well-drained soils of moderately slow permeability. Solum thickness ranges from 50 to 122 cm and corresponds to the depth of the petrocalcic horizon. Coarse fragments of limestone comprise less than 15 percent of the control section. When dry, the soil has cracks from 1 to 2 cm wide and 25 to 50 cm deep. Texture of all horizons ranges from silty clay to clay. Clay content ranges from 40 to 50 percent.

Throck Soil Series. This series is a member of the fine, mixed, thermic family of Typic Ustochrepts. These soils are moderately deep, calcareous, well-drained, and slowly permeable. They formed in clayey marl and shaly clay on gently sloping to steep uplands. Slopes range from 1 to 30 percent. Solum thickness ranges from 53 to 127 cm. Texture of the A and B horizons is clay loam, silty clay loam, silty clay, or clay. Clay content of the control section is 35 to 45 percent. Most pedons are calcareous throughout.

Nukrum Soil Series. The Nukrum series is a member of the fine, mixed, thermic family of Vertic Haplustolls. It consists of deep, well-drained, moderately slow, permeable soils formed in alkaline clayey sediments. These upland soils have slopes ranging from 0 to 5 percent. Solum thickness ranges from 107 to 183 cm. These soils, when dry, have cracks 1 to 3 cm wide that extend from the surface to depths exceeding 50 cm. The 25-to-100-cm control section is texturally classified as silty clay, clay, or clay loam, as clay content ranges from about 38 to 60 percent clay.

Rowena Soil Series. The Rowena series is a member of the fine, mixed, thermic family of Vertic Calciustolls. It consists of deep, well-drained, moderately slowly permeable soils that formed in loamy and clayey sediments. These soils are on nearly level to gently sloping upland plains. Slopes are from 0 to 3 percent. Solum thickness ranges from 56 to 122 cm. Distinct calcium carbonate accumulations begin at depths ranging from 60 to 100 cm. When dry, cracks 1 to 3 cm wide extend from the surface to a depth of 50 to 75 cm.

Nuvalde Soil Series. The Nuvalde series is a member of the fine-silty, mixed, thermic family of Typic Calciustolls. It consists of deep, well-drained, moderately permeable soils that formed in limy alluvium. These soils are located on nearly level to gently sloping uplands. Slopes range from 0 to 5 percent. Solum thickness ranges from 50 to 100 cm. The weighted average of the total clay content of the 25 to 100 cm control section ranges from 35 to 50 percent, with silicate clay content ranging from 25 to 35 percent.

Rocky Hills Range Site

The Rocky Hills range site occurs on the steeper hillsides. It often appears on slopes near drainageways and on escarpments immediately below high plateaus. The soils of this site are dark grayish brown clays 30 to 45 cm deep. They are highly calcareous, stony, and granular clays that grade into marls or shaley clays. Thin layers of limestone bedrock occasionally outcrop on this site. The soils are moderate to slowly permeable. Water storage capacity is generally high. The climax plant community is considered to be a mixture of tall- and midgrasses with a scattering of woody plants. The dominant tallgrasses are big bluestem, Indiangrass, and switchgrass. The dominant midgrasses are little bluestem and sideoats grama.

Throck Soil Series. The Throck series is a member of the fine, mixed, thermic family of Typic Ustochrepts. These soils are moderately deep, calcareous, well-drained, and slowly permeable. They formed in clayey marl and shaly clay on gently sloping to steep uplands. Slopes range from 1 to 30 percent. Solum thickness ranges from 50 to 125 cm. Texture of the A and B horizons is clay loam, silty clay loam, silty clay, or clay. Clay content of the control section is 35 to 45 percent. Most pedons are calcareous throughout.

Clay Flat Range Site

This site occurs on nearly level to gently sloping upland flats or in broad valleys. Slopes generally range from 0 to 3 percent. The soils on this site are deep, calcareous clays and silty clays. They have high shrink-swell capacities which result in large surface cracks when dry. Rate of water infiltration is rapid when the soils are dry and very slow when the soils are wet. The climax plant community is an open midgrass dominant. Sideoats grama and Texas wintergrass are the dominant grasses found on the site. Estimated annual herbage yields on areas in excellent range condition vary from 2,800 to 5,000 kg/ha depending upon rainfall.

Leeray Soil Series. The Leeray series is a member of the fine, montmorillonitic, thermic family of Typic Chromusterts. It consists of deep, well-drained, very slowly permeable, clayey soils that formed in calcareous, clayey sediments. These soils are in valleys or on stream divides. Slopes range from 0 to 5 percent. This is a cyclic soil with solum 102 cm to more than 203 cm thick. In undisturbed areas there is gilgai microrelief with microknolls 10 to 30 cm higher than microdepressions. When the soil is dry, cracks 2 to 8 cm wide form from the surface to a depth of greater than 50 cm. Intersecting slickensides begin at depths of 38 to 60 cm. The soil is moderately alkaline and calcareous clay or silty clay throughout with 40 to 60 percent clay. This soil is siliceous predictable.

Loamy Bottomland Range Site

This site occurs on nearly level to gently sloping land adjacent to rivers and streams. The alluvial soils of this site are deep and of medium and fine texture. They are moderately permeable and fertile. They receive overflow water frequenctly from nearby streams and runoff water from adjacent uplands. Deposition of silt and debris is common on this site following overflow. The climax plant community is considered to be a mixture of tall- and midgrasses with an abundance of forbs and woody plants. Dominant midgrasses are little bluestem, vine-mesquite, and sideoats grama. The dominant tallgrasses are Indiangrass, switchgrass, and big bluestem. The density of woody species varies with the frequency and amount of overflow.

Frio Soil Series. The Frio series are fine, mixed, thermic Cumulic Haplustolls. It consists of deep, well-drained, moderately slow permeable soils that formed in loamy and clayey calcareous alluvium. Soils have slopes ranging from 0 to 2 percent. These soils are inundated with overflow as often as twice a year. The calcium carbonate equivalent of the 25-to-90-cm control section ranges from 10 to 40 percent. Depth of gravel, sand, or limestone ranges from 6 to 30 feet.

Spur Soil Series. The Spur series is a member of the fine-loamy, mixed thermic family of Fluvenic Haplusfalls. These calcareous soils have dark brown clay loam A horizons over stratified brown clay loams. These soils occur on nearly level flood plains. They are formed from calcareous loamy alluvium. They are well-drained, moderately permeable soils that are infrequently flooded.

Very Shallow Range Site

This site occurs on gently sloping to steep upland areas. It may occur as knolls within other sites. Slopes range from 1 percent to greater than 8 percent. This site is well-drained and has medium to rapid surface runoff. Permeability is moderate. The climax plant community is composed primarily of mid- and shortgrasses with small amounts of tallgrasses. The dominant midgrasses are sideoats grama, little bluestem, and Texas wintergrass. The dominant shortgrass is buffalograss. There is normally a wide variety of forbs and woody species present. Herbage production is limited by shallow soil depth. Estimated annual herbage yields on this site vary from 500 to 1,700 kg/ha depending upon annual rainfall and range condition.

Leuders Soil Series. The Leuders series is a member of the loamy-skeletal, carbonatic, thermic Lithic Calciustolls. It consists of very shallow and shallow, well-drained, moderately permeable soils formed in residuum from indurated limestone. These upland soils have slopes that range from 1 to 25 percent. Solum thickness ranges from 18 to 50 cm and commonly is the same as the depth to bedrock. The control section contains from 35 to 80 percent limestone fragments that are less than 25 cm across the long axis.

Shallow Range Site

This site occurs as gently sloping areas on footslopes and divides. Slopes generally range from 2 to 8 percent. This site is well-drained with slow to medium surface runoff. Permeability and water storage capacity are moderate. The climax plant community is dominated by midgrasses with some tallgrasses and woody plants present. The tallgrasses and woody plants usually occur in the vicinity of limestone outcrops, drains, or crests of hillsides. The dominant midgrasses are sideoats grama, little bluestem, cane and silver bluestem, Arizona cottontop, vine-mesquite, Texas cupgrass, buffalograss, curlymesquite, slim and rough tridens, white tridens, and purple and Wright's threeawn. The dominant tallgrasses are big bluestem and Indiangrass. The site generally supports a wide variety of forb species. Estimated annual herbage yield from sites in excellent range condition vary from 1,700 to 3,300 kg/ha depending upon rainfall.

Mereta Soil Series. The Mereta series is a member of the clayey, mixed, thermic, shallow family of Petrocalcic Calciustolls. These soils have dark grayish brown to dark brown calcareous clay loam A horizons underlaid by a strongly cemented caliche layer within 50 cm of the surface. They are well-drained soils, and runoff and permeability are slow. Permeability in the petrocalcic horizon is slow to very slow. Solum thickness to the strongly cemented or indurated petrocalcic horizon ranges from 36 to 50 cm. The texture of the soil extending from a depth of 25 cm to the petrocalcic horizon ranges from clay to clay loam. Coarse fragments are generally absent in the profile although some pedons may contain some hard angular caliche.

Shallow Clay Range Site

This site occurs on nearly level to steep sloping uplands. Slopes range from 1 to 12 percent. Vegetation is dominated by a mixture of short- and midgrasses. Sideoats grama is the dominant midgrass. Little bluestem may occur in areas where favorable moisture and soil development conditions exist. Estimated annual herbage yields on areas in excellent range condition vary from 550 to 2,300 kg/ha depending upon rainfall.

Owens Soil Series. The Owens series is a member of the clayey, mixed, thermic, shallow family of Typic

Ustochreptis. It consists of well-drained soils with rapid runoff and very slow permeability. These clayey soils have light olive brown A horizons, olive brown B horizons with blocky structure, and shaly clay C horizons within 50 cm of the surface. The solum ranges from 25 to 50 cm in depth. The soil is generally considered moderately alkaline although some pedons are noncalcareous in the A horizon.

Deep Redland Range Site

This site occurs as nearly level to gently sloping uplands of undulating landscape. Slopes are generally less than 2 percent. The site includes both low ridgetops and intervening slopes. The climax plant community is an open grassland dominated by tallgrasses. The dominant tallgrasses are big bluestem and Indiangrass. The dominant midgrasses are little bluestem, sideoats grama, tall dropseed, and silver bluestem. Estimated annual herbage yield on sites in excellent range condition vary from 3,300 to 6,700 kg/ha depending upon rainfall.

Rowden Soil Series. The Rowden series is a member of the fine, mixed, thermic family of Typic Argiustolls. It consists of moderately deep, well-drained, slowly permeable soils that formed in loamy and clayey material over hard limestone. These soils are on nearly level to gently sloping uplands. Slopes range from 0 to 3 percent. Solum thickness ranges from 50 to 100 cm. The lower boundary of the solum either rets abruptly on limestone bedrock or grades into bedded limestones with soil occupying the interstices. Coarse fragments and gravel content range from 0 to 15 percent in the A and B horizons.

APPENDIX 6. TAXONOMIC LIST AND ECOLOGICAL CLASSIFICATION OF PLANTS FOUND AT THE TEXAS EXPERIMENTAL RANCH (AFTER GOULD 1975, CORRELL AND JOHNSTON 1970)

Scientific Name	Common Name
I. Grasses	
A. Cool Season	
1. Annuals	
*Avena fatua	Wild oat
*Bromus japonicus	Japanese brome
*Bromus unioloides	Rescuegrass
Hordeum pusillum	Little barley
Limnodea arkansana	Ozarkgrass
*Phalaris caroliniana	Carolina canarygrass
Trisetum interruptum	Prairie trisetum
*Triticum aestivum	Wheat
*Triticum cylindricum	Jointed goatgrass
Vulpia octoflora	Common sixweeksgrass
2. Perennials	
Agropyron smithii	Western wheatgrass
Elymus canadensis	Canada wildrye
Hordeum jubatum	Foxtail barley
Poa arachnifera	Texas bluegrass
Sphenopholis obtusata	Prairie wedgescale
Stipa leucotricha	Texas wintergrass
B. Warm Season	
1. Annuals	
*Echinochloa crusgalli	Barnyardgrass
*Eragrostis cilianensis	Stinkgrass
Eragrostis hypnoides	Teal lovegrass
Eriochloa contracta	Prairie cupgrass
Leptochloa filiformis	Red sprangletop
Panicum capillare	Common witchgrass
Panicum fasciculatum	
2. Perennials	
Andropogon gerardii	Big bluestem
Aristida longiseta	Red threeawn

*Introduced species

Aristida wrightii	Wright threeawn
*Bothriochloa ischaemum	King Ranch bluestem
Bothriochloa saccharoides	Silver bluestem
Bouteloua curtipendula	Sideoats grama
Bouteloua gracilis	Blue grama
Bouteloua hirsuta	Hairy grama
Bouteloua rigidiseta	Texas grama
Buchloe dactyloides	Buffalograss
Cenchrus incertus	Coast sandbur
Chloris verticillata	Tumble windmillgrass
*Cynodon dactylon	Bermudagrass
Digitaria californica	Arizona cottontop
Eragrostis curtipedicellata	Gummy lovegrass
Eriochloa sericea	Texas cupgrass
Erioneuron pilosum	Hairy erioneuron
Hilaria belangeri	Common curlymesquite
Hilaria mutica	Tobosa
Ledptoloma cognatum	Fall witchgrass
Panicum hallii	Halls panicum
Panicum hians	Gaping panicum
Panicum obtusum	Vine-mesquite
Panicum virgatum	Switchgrass
Schedonnardus paniculatus	Tumblegrass
Schizachyrium scoparium	Little bluestem
Setaria leucopila	Plains bristlegrass
Sorghastrum nutans	Yellow Indiangrass
*Sorghum halepense	Johnsongrass
Sporobolus asper	Tall dropseed
Sporobolus cryptandrus	Sand dropseed
Sporobolus pyramidatus	Whorled dropseed
Tridens albescens	White tridens
Tridens muticus	Slim tridens
II. Grass-Likes	
Carex spp.	Sedge
Cyperus spp.	Flatsedge
Eleocharis spp.	Spikesedge
Juncus spp.	Rush
Scirpus spp.	Bulrush
Typha spp.	Cattail
III. Forbs	
A. Cool Season	
1. Annuals	
Ammoselinum popei	Plains sandparsley
Argemone albiflora	White pricklypoppy
Astragalus distortus	Bentpod loco
Astragalus nuttallianus	Nuttall milkvetch
*Capsella bursa-pastoris	Shepherds purse
Centaurea americana	American basketflower
Cerastium texana	Texas chickweed
Chaerophyllum tainturieri	Hairyfruit chervil
Daucus pusillus	Southwestern carrot
Descurainia pinnata	Pinnate tansymustard
*Descurainia sophia	Flixweed tansymustard
Draba cuneifolia	Wedgeleaf draba
*Erodium cicutarium	Alfilaria
Erodium texanum	Texas fillaree
Euphorbia spathulata	Warty euphorbia
Evax multicaulis	Manystem evax
Galium virgatum	Southwest bedstraw
Gaura tripetala	Three petal guara
Geranium texanum	Texas geranium
Lappula redowskii	Flatspine stickseed

Lepidium austrinum	Southern pepperweed
Lepidium densiflorum	Prairie pepperweed
Lesquerella gordonii	Gordon bladderpod
Linaria texana	Texas toadflax
Lindheimera texana	Texas-star
*Medicago minima	Small medic
Plantago aristata	Bottlebrush plantain
Plantago rhodosperma	Redseed plantain
Scutellaria drummondii	Drummond skullcap
Senecio imparipinnatus	Groundsel
Sibara virginia	Virginia sibara
Silene antirrhina	Sleepy catchfly
Tetraneuris linearifolia	Fineleaf tetraneuris
Torilis nodosa	Knotted hedgeparsley

2. Perennials

Achillea millefolium	Common yarrow
Allium drummondii	Drummond onion
Amsonia ciliata	Texas slimpod
Androstephium caeruleum	Blue funnellily
Anemone decapetala	Tenpetal anemone
Astragalus plattensis	Ground plum
Callirhoe digitata	Finger poppymallow
Cymopterus macrorhizus	Bigroot wavewing
Delphinium virescens	Plains larkspur
Dianthera americana	Dense flowered waterwillow
Engelmannia pinnatifida	Englemann daisy
Erigeron tenuis	Slender fleabane
Gaura filiformis	Tall gaura
Lithospermum incisum	Narrowleaf gromwell
Nemastylis geminiflora	Prairie pleatleaf
Northoscordum bivalve	Yellow falsegarlic
Oenothera laciniata	Cutleaf evening-primrose
Oenothera triloba	Stemless evening-primrose
Orobanche ludoviciana	Louisiana broomrape
Penstemon cobaea	Cobaea penstemon
Psoralea cuspidata	Tallbread scurfpea
Pyrrhopappus grandiflorus	False dandelion
Sisyrinchium bermudiana	Bermuda blue-eyegrass
Tradescantia occidentalis	Prairie spiderwort
Tradescantia ohioensis	Ohio spiderwort

B. Warm Season

1. Annuals

*Amaranthus blitoides	Prostrate pigweed
Ammannia coccinea	Purple ammannia
Aphanostephus ramosissimus	Lazy daisy
Aster subulatus	Aster
Conyza canadensis	Horse-weed
Croton monanthogynus	Oneseed croton
Eclipta alba	Herbadetago
Eryngium leavenworthii	Leavenworth eryngo
Euphorbia marginata	Snow-on-the-mountain
Euphorbia missurica	Prairie euphorbia
Euphorbia prostrata	Prostrate euphorbia
Euphorbia serpens	Mat euphorbia
Eustoma grandiflorum	Showy prairie gentian
Gaillardia pulchella	Firewheel
Gaura parviflora	Small flower gaura
Helenium amarum	Bitterweed
Helenium microcephalum	Sneezeweed
Helianthus annuus	Common sunflower
Hymenoxys odorata	Bitterweed
Kallstroemia hirsutissima	Hairy caltrop

*Kochia scoparia	Belvedere
*Lactuca serriola	Prickly lettuce
Linum pratense	Meadow flax
Martynia louisianica	Common devilclaw
Monarda pectinata	Plains beebalm
Polanisia dodecandra	Roughseed clammyweed
Polygonum texensis	Knotweed
Portulaca oleracea	Common portulaca
Proboscidea louisianica	Common devilclaw
Rorippa sessiliflora	Stalkless yellowclaw
Rudbeckia amplexicaulis	Clasping coneflower
*Salsola kali	Russianthistle
Solanum rostratum	Buffalobur
*Sonchus asper	Sow thistle
Tidestramia lanuginosa	Wolly tidestromia
*Tragopogon dubius	Goat's-beard
*Tribulus terrestris	Puncturevine
Triodanis leptocarpa	Slimpod Venuslookingglass
Verbena bipinnatifida	Dakota verbena
Verbena bracteata	Bigbract verbena
Verbena pumila	Pink vervain
Verbena xutha	Coarse verbena
Xanthium italicum	Cocklebur
Xanthocephalum dracunculoides	Annual broomweed
Xanthocephalum texanum	Texas broomweed
2. Perennials	
Abutilon incanum	Indianmallow
Ambrosia psilostachya	Western ragweed
Apocynum cannabinum	Hemp dogbane
Argythamnia humilis	Low wildmercury
Argythamnia mercurialina	Tall wildmercury
Artemisia ludoviciana	White sage
Asclepias asperula	Spider antelopehorn
Asclepias engelmanniana	Engelman milkweed
Asclepias latifolia	Broadleaf milkweed
Aster ericoides	Heath aster
Aster oblongifolius	Aromatic aster
Cassia pumilio	Dwarf senna
Cassia roemeriana	Twoleaf senna
Chamaesaracha sordida	Hairy false-nightshade
Cirsium ochrocentrum	Yellow-spine thistle
Cirsium texanum	Texas thistle
Cirsium undulatum	Wavyleaf Thistle
*Convolvulus arvensis	Field bindweed
Cucurbita foetidissima	Buffalogourd
Dalea aurea	Golden dalea
Dalea enneandra	Bigtop dalea
Desmanthus illinoensis	Illinois bundleflower
Desmanthus leptolobus	Prairie bundleflower
Dyschoriste linearis	Narrowleaf dyschoriste
Dyssodia pentachaeta	Parralena
Eriogonum lachnogynum	Wildbuckwheat
Erigeron tenuis	Slender fleabane
Euphorbia albomarginata	Spurge
Evolvulus aslinoides	Slender evolvulus
Gaillardia suavis	Indian blanket
Gaura coccinea	Scarlet gaura
Grindelia squarrosa	Curlycup gumweed
Heterotheca canescens	Camphor weed
Hedeoma drummondii	Drummond hedeoma
Heliotropium currassavicum	Salt heliotrope
Hoffmanseggia densiflora	Indian rushpea

Hybanthus verticillatus	Whorled nodviolet
Hymenopappus tenuifolius	Woollywhite
Krameria lanceolata	Trailing ratany
Kuhnia eupatorioides	False boneset
Liatris punctata	Dotted gayfeather
Lygodesmia texana	Skeletonplant
Machaeranthera pinnatifida	
Matelea biflora	Twoflower milkvine
Melampodium leucanthus	Plains blackfoot
Mentzelia multiflora	Desert mentzelia
Mentzelia oligosperma	Chickenthief
Mirabilis linearis	Linearleaf four-o'clock
Oenothera missouriensis	Gray sundrop
Oenothera speciosa	Showy sundrop
Oxalis dillenii	Yellow woodsorrel
Petalostemum multiflorum	Round-head prairie-clover
Phyla incisa	Sawtooth fogfruit
Phyllanthus polygonoides	Knotweed leafflower
Physalis lobata	Purple groundcherry
Physalis viscosa	Field groundcherry
Pinaropappus roseus	Rock-lettuce
Polygonum ramosissimum	Bushy knotweed
*Rumex crispus	Curly dock
Salvia azurea	Azurea sage
Salvia farinacea	Mealycup sage
Sarcostemma crispum	Wavyleaf twinevine
Sarcostemma cynanchoides	Twinevine
Schrankia uncinata	Catclaw sensitive briar
Scutellaria resinosa	Resindot skullcap
Sida filicaulis	Spreading sida
Sida physocalyx	
Solanum elaeagnifolium	Silverleaf nightshade
Solidago gigantea	Goldenrod
Solidago petiolaris	Goldenrod
Sphaeralcea coccinea	Scarlet globemallow
Tetraneuris scaposa	Plains tetraneuris
Teucrium laciniatum	Germander
Thelesperma filifolium	Greenthread
Thelesperma megapotamicum	Greenthread
Tragia nepetaefolia	Catnip noseburn
Vernonia baldwinii	Baldwin ironweed
Vernonia marginata	Plains ironweed

IV. Succulents (all-perennial)

A. Cool Season

Coryphantha vivipara	
Echinocactus texensis	Devils pincushion
Echinocereus reichenbachii	Lace echinocereus
Opuntia phaecantha	Brownspine pricklypear

B. Warm Season

Opuntia leptocaulis	Pencil cholla

V. Trees, Shrubs, and Woody Vines (all perennial)

A. Cool Season

Amorpha fruiticosa	Indigobush
Celtis reticulata	Netleaf hackberry
Salix nigra	Black willow
Sapindus drummondii	Western soapberry
Ulmus americana	American elm
Yucca pallida	Spanish bayonet
Zanthoxylum hirsutum	Toothache tree

B. Warm Season

Bumelia lanuginosa	
Cephalanthus occidentalis	Common buttonbush

Cissus incisa	Ivy treebine
Condalia obtusifolia	Lotebush
Juniperus pinchoti	Redberry juniper
Lycium berlandieri	Berlandier wolfberry
Mimosa biuncifera	Catclaw mimosa
Prosopis glandulosa	Honey mesquite
Prunus rivularis	Creek plum
*Tamarix gallica	Saltcedar

APPENDIX 7. NUMBER OF PERMANENT VEGETATION SAMPLE PLOTS BY RANGE SITE, SOIL SERIES, AND GRAZING TREATMENT, UTILIZED IN STUDY FROM 1960 THROUGH 1978

		Grazing Treatment			
Range Site	Soil Series	HC	MC	DR	EX
Clay Loam	Sagerton	1	0	0	0
	Valera	7	2	4	0
	Throck	7	11	20	4
	Nukrum	13	15	6	7
	Rowena	5	12	17	12
	Nuvalde	5	5	8	4
Rocky Hills	Throck	3	4	0	0
	Owens	3	2	0	0
Clay Flat	Leeray	4	2	26	11
Loamy Bottomland	Frio	15	8	19	10
	Spur	3	0	0	0
Very Shallow	Leuders	6	5	6	1
Shallow	Mereta	2	5	6	4
Shallow Clay	Owens	6	14	7	6
Deep Redland	Rowden	3	2	1	10
	Lindy	0	1	0	0
Low Stoney Hill	Palopinto	1	1	0	0
Redland	Speck	0	0	0	1

METRIC UNITS — ENGLISH EQUIVALENTS

Metric Unit	*English Equivalent*
Centimeter	0.394 inch
Hectare	2.47 acres
Kilogram	2.205 pounds
Kilogram per hectare	0.893 pounds per acre
Kilometer	0.62 statute mile
Kilometer per hour	0.62 miles per hour
Liter	0.264 gallons
Meter	3.28 feet
Square meter	10.758 square feet
(Degrees centigrade × 1.8 + 32)	Degrees Fahrenheit

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